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The predictive power of the term structure in Norway

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ABSTRACT

The aim of this thesis is to study if the term structure is a good predictor of Norwegian real economic activity and whether it can be used as a forecasting tool in real time or not. We study both theoretical and empirical explanations. Some of the models are replicated from international studies and others are created based on our perception of theory and adjusted to Norwegian conditions. All results indicate that the term structure contains information about Norwegian real economic activity, although the results are not as evident compared to the US. The results imply that it is useful to control for the influence of the oil sector and international term spreads. Characteristics of the term structure as a leading indicator makes it useful as an additional supplement to other leading indicators.

PREFACE AND ACKNOWLEDGEMENTS

Our sincere interest in macroeconomics and financial theory is the motive for writing this thesis. We were looking for a topic that we felt would cover these subject areas. The idea to study the predictive power of the term structure was sparked in spring 2007 during a lecture in the course 'Konjunkturanalyse' at NHH, held by Jan Tore Klovland. The fact that there was no established theory on this topic and the lack of comprehensive studies on Norwegian data was appealing.

Our study of the predictive power of the Norwegian term structure is associated with a few limitations. Limited availability of Norwegian data can make the time periods to small to generalize. Norwegian interest rates are dependent on international interest rates and this characteristic might weaken the results. We have treated the topic as if there was an established theory; this is controversial in academia.

Our study also contains a number of strengths. We have estimated a variety of models. This includes models that are identical and comparable to foreign literature. We also estimate models that are based on our own perception of theory and adjusted to country specific factors in Norway.

We want to thank professor Jan Tore Klovland for accepting to supervise this thesis. Jan Tore has always been available and open to give suggestions. He has provided valuable guidance and insights. We also want to thank Arturo Estrella, Deutsche Bundesbank, Eurostat, Statistics Norway and Norges Bank for useful information and data.

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1. Introduction

Since the eighties economists have argued that the term structure contains information on future economic activity. Empirical research in the US has found that when short-term interest rates rise above long-term interest rates, known as an inversion of the term structure, it has signaled a recession. Before each of the six last US recessions the term structure has been inverted some time in advance, usually around four to six quarters ahead of the recession (Estrella & Mishkin 1997). If this is consistent and the term structure is reliable as a leading indicator, it provides i.e. monetary authorities or market speculators with a very valuable prediction tool of future real economic activity. There are three substantial advantages of the term structure as a predictor of real economic activity compared to other leading indicators. First, the term structure has longer lead time than any other regular leading indicators. Second, compared to some other leading indicators the term structure is not object to considerable revision retrospectively. Third, the term structure is easy to compute and is ready available.

Research has found that the term structure contain predictive power of economic activity in the following measures; GNP and GDP growth, growth in consumption, investment and industrial production and economic recessions dated by the National Bureau of Economic Research (NBER).[1]

This thesis focuses on how well the term structure predicts real economic activity in Norway. Other studies primarily in the US have found that the term structure explain as much as 30 percent or more of the variation in the measure of GDP growth (Estrella & hardouvelis 1991). Our null-hypothesis is that there is no information regarding the real economic activity in the term structure. Alternatively, there is some information in the term structure. This hypothesis is examined using a quantitative approach, including correlation analysis and various regression models. There has been used quite a variety of models in similar studies. This variety seems to underline the theoretical controversy regarding the information in the term structure; the models that find the most information are the probit models. These are reduced form

[1] Estrella (2005b): Yield curve FAQ: http://www.ny.frb.org/research/capital_markets/ycfaq.html

estimations, and say nothing about the causality in the relationship. Structural models, using OLS, generally find less information. This is where the controversy arises. Reduced form estimation generates heuristic theories. Perhaps the limited evidence of structural models is caused by an inadequate causal relation between the term spread and real economic activity. In order to reject or not reject the null-hypothesis with more certainty, this quantitative approach use both structural and reduced estimation techniques.

The hypothesis is of such a character that it becomes necessary to look into related fields of research such as monetary policy's role, international term spreads the risk premium in the term structure, country specific factors and events, and the term spread's stability over time. Our models are not adjusted to address these issues properly. We just consider these issues as possible explanations for the information content of the term spread. Furthermore, we consider the sample period of 1985-2007, due to non-existence of necessary Norwegian data outside this sample. We consider the US and German term spreads as the most important for the Norwegian real economic activity, and excludes other countries term spreads. We assume that they either affect real economic activity in Norway directly through expectations, or indirectly through expectations on a global business cycle or an international term spread. We also control for the influence of the oil sector upon real economic activity due to its particular importance in Norway.

In 1998 Isachsen et.al did a comparison of different leading indicators where they tested their predictive power on Norwegian real economic activity. Although their sample is short (they only have data from 1991 to 1996), their result indicate that the term structure alone give equally good or even better predictions of future real economic activity than the usual indexes of leading indicators. They compare the term structure against predictions from OECD, SSB, Norges Bank, Finansdepartementet, NHO, Bankforeningen and Kreditkassen. Similar results have also been found in other countries (Estrella & Mishkin 1998, Dueker 1997, Dotsey 1998 and Stock & Watson 2003). I.e. Stock and Watson (2003) compared a large number of leading indicators where they focused on how well they explained real economic growth. They found that the term structure outperforms the other leading indicators. The drawback is that the term structure seems to contain some instability. However, the nature of this instability seems sufficiently idiosyncratic, so combining the term structure with some other leading indicators probably will improve its performance and make it a more reliable leading indicator.[1]

The term structure has predicted real economic activity particularly good in the US.[1] However, some recent studies have indicated that the predictive power of the term spread might have undergone a structural change. If this is the case, the term structure may no longer be a robust predictor of business cycles.[1]

We first present a short overview over the theoretical foundation concerning the term structures predictive abilities. The data material is presented in part three. Part 4 present some econometric issues that are important for all our models. In the next parts we present each model and its results together. Part 5 present correlation analysis and OLS models. Part 6 presents another OLS model following the approach of Estrella & Hardouvelis (1991). Part 7 present the probit models. Part 8 present out-of-sample forecasts. Finally, we sum up and discuss our main findings in part 9, before drawing a conclusion in part 10.

Literature – survey

In this section we present and overview of earlier research on the term structure. The section is based on Estrellas yield curve FAQ, which provide a good overview over existing research on the subject.[1] Among other things, we will see how and when the relationship between the term structure and real economic activity were discovered. Research on information drawn from interest rates with different maturities goes back at least to Mitchell (1913). However, according to Estrella, Kessel (1965) might have been the first to make specific references to the term structure as a leading indicator. Kessel observed that the term spread between long-term and short-term maturities tend to be low or negative in the beginning of a recession and increasing as the economy began to catch up again.

Butler (1978) discovered a connection between the term structure as a leading indicator of short-term interest rates and the implications of decreasing short-term interest rates on the real economic activity. In 1988/1989 Laurent used the term structure to predict GDP growth.

Harvey (1988) developed a theoretical connection between the term spread and preceding real consumption growth. His theories were also backed up by empirical research. One year later Furlong (1989) found some evidence that the term spread to some degree could predict recessions. However, he didn't feel that the term structure was a reliable leading indicator.

Arturo Estrella, who currently is working in the Federal Reserve Bank of New York, is considered one of the world's leading expert on theories about the term structure. Together with Hardouvelis (1989, 1990 and 1991) they found empirical evidence that the term structure not only had predicted the NBER-dated recessions, but also real growth in consumption, investments and aggregated GNP. In 1997 Estrella and Mishkin examined the relationship of the term structure and monetary policy instruments to subsequent real activity and inflation on both Europe and the US. They found evidence that monetary policy is an important determinant of the term structure. However, monetary policy is unlikely to be the only determinant, since the term structure seems to have explanatory power under different monetary regimes. They also found that the term spread had significant predictive power for both real economic activity and inflation (Estrella & Mishkin 1998). Bernard & Gerlach (1996) is another study which investigates the predictive power of the term structure internationally, testing in eight different countries. Although, with varying strength, they found that the term structure provides information about future business cycles in all eight countries.

In 2006 Estrella and Trubin found that before each of the last six US recessions the short-term interest rates rose over long-term interest rates and the term structure has been inverted. Wright (2007) provides an interesting study using different spread related measures (such as interest rate risk premium) to overcome some of the simplifying assumptions of the earlier models.

There has been little research on the predictive power of the Norwegian term structure. Isachsen et.al (1998) use the same method as Estrella & Mishkin (1998) and obtain results that are qualitatively equal, but not as strong. Gerdrup (2006) test the predictive abilities of different financial variables over real economic activity. The model complies well with the international literature.

2. Theory

The relationship between the term spread and real economic activity has been established as an empirical connection. The 'theory' consists of a set of different explanations based on the empirical findings. While they are mutually exclusive, they cannot be said to form a single theoretical foundation. The lack of one solitary explanation has brought forward the question of whether the relationship is a coincidence or not.

2.1 Theoretical explanations of the term structure as a leading indicator

The term structure has empirically been established as a leading indicator for business cycles internationally in example by Bernard & Gerlach (1996), Estrella & Mishkin (1997), Hardouvelis & Malliaropolus (2004). However, the lack of a single accepted theoretical basis behind this relationship calls for a review of the different suggested foundations (Estrella & Trubin 2006).

First, from a monetary policy approach, an inverted term structure is associated with real economic activity because the central bank influences the short-term interest rate more than the longer term interest rates. Since the effect of an increased short-term interest rate will reduce real economic activity in the future, the tightening of monetary policy will invert the term structure and give expectations of a future real economic slowdown.

Second, the term structure can reflect investor's expectations of future real economic activity. This effect influences the long end of the term structure more than the short. In a situation where the market participants expect a decrease in future real economic activity, the term structure will invert because of decreased inflation expectations. This effect depends on the prevailing monetary regime.

Third, the corporations considering undertaking investments will postpone these when future real economic activity is expected to slow down. This reduces the demand for long-term credit, and thus lowers the yield on such instruments. This inverts the term structure, as long-term interest rates decrease.

Whether the shift occurs in the short or long end of the term structure, this can be related to the mechanisms above. These explanations all have in common that a less steep or declining term structure is associated with a reduction in real economic growth sometime in the future (Isachsen 1998). The effects of these explanations can in theory occur at the same time. That is, shifts in both the short and long end of the term structure can occur at the same time and for more than one of the reasons mentioned above. In example, it is not difficult to imagine a long end shift of the term structure as a result of both investor's expectations and reduced demand of long-term interest rate instruments. The explanations are therefore to a small degree mutually exclusive.

2.2 The risk premium in the term structure – the different hypothesis.

It is useful to know whether the term structure really reflects the market's expectations or whether it is biased in some way. This is important to this study, because it influences the information content in the term structure. Is the term structure we observe really what the market expect or is there other factors affecting the term structure? There are some different theories. Most empirical research suggests that we should include a risk premium in the term structure. However, as we will discuss below determining the risk premium is far from easy since it seems to vary over time and business cycles. Besides discussing the risk premium hypothesis we will also briefly describe two other hypotheses in this section, namely the expectations hypothesis and preferred maturity hypothesis[2]. This presentation is based on the work of Valseth (2003) on the importance of the term premium and interest rate expectations.

Expectations hypothesis

The expectations hypothesis assumes that the long-term interest rates are the markets unbiased estimate on future short-term interest rates in the period. If this hypothesis is correct there is an unambiguous connection between the term structure and the markets interest rate expectations. If the term structure is upward sloping the market is expecting higher interest rates and vice versa if the term structure is downward sloping.

Preferred maturity hypothesis

Investors have different preferences on time to maturity. In example, insurance companies or pension funds wants maturities that matches their obligations. If this is the only aspect that determines the term structure, there is no connection between the term structure and the markets interest rate expectations. Instead each term has to be analyzed from supply and demand in that segment. Inversions in the term structure, does not necessarily reflect expectations of future real economic activity under this hypothesis. It could very well represent

[2] In Norwegian: Segmenterings hypotesen.

an increased demand for long- term bonds. Empirical research gives little support to the preferred maturity hypothesis.

Risk premium hypothesis

Given that the investors have risk aversion, the long-term interest rates will become a weighted average of the observed interest rate in the actual period and the markets future short-term interest rates plus a positive risk premium. This means that there no longer is a defined connection between the term structure and future interest rate expectations. I.e. a slightly upward sloping term structure does not necessarily mean that the market is expecting higher interest rates in the future, but can instead be the result of a risk premium that increases with the time horizon.

There are three types of risk premiums; credit premium, liquidity premium and the term premium. The *credit premium* is a compensation that the investor demands because of the possibility that a borrower does not fulfill the obligations agreed upon. The size of the credit premium will depend on the counterparts' credit rating and usually increase as the duration increases. Typically government obligations who usually are rated AAA (as rated by Standard & Poor's) therefore contain a very small amount of credit premium. Since Norway is a rich and political stable country we assume that the credit premium on Norwegian state certificate and obligations are practically zero.

Small markets are characterized by few transactions and high bid-ask spread. In such a market an investor might find it difficult to sell the instrument. Being aware of this the investors will demand a compensation, which we refer to as the *liquidity premium*. The market for bonds issued by the Norwegian government is quite small and we therefore expect a liquidity premium.

When an investor has different maturity on his investment than the instrument he buys, it will cause him some uncertainty about the future value of the instrument because the interest rate might change. The premium that the investors demand for this interest rate risk is known as the *term premium*.

The risk premium will vary over time. Knowing this it is difficult to determine what the market expects that the long-term interest rate will be. However, we do have some earlier research to rely on. Empirical research has shown that the risk premium is counter-cyclical to the market. Meaning that in a bear market the risk premium is high and in a bull market the risk premium is low. Studies done by Myklebust (2005) indicate that in 'normal' times the risk premium is between 20 and 40 basis points on interest rates with duration over one year. Since the second half of 2007 (Norges Bank 2007), we have seen a considerable increase in the risk premium internationally and to some degree also in Norway. It is the market turmoil caused by the collapse of the subprime-market in the US that has lead to increased risk premiums.

Since the risk premium is unstable and changes depending on i.e. business cycles we have decided not to include a risk premium in the models we present in part 5, 6 and 7. Although there is little empirical support for the expectation hypothesis we feel that it is the most proper assumption, because we study inversion in government securities. Estimating a risk premium might increase the uncertainty of the results. Anyhow, the risk premium will probably be higher for ten-year Treasury bonds than for three-month Treasury bills. Not including a risk premium would increase the term spread, rather than decrease it, assumed a positive risk premium. Although, the expectations hypothesis is associated with limited empirical support, assuming it in our study will decrease the risk of observing false recession signals.

2.3 Monetary policy's role

To examine whether there are differences in the information in the term structure depending on the monetary policy regime, we provide a theoretical description of this link in this section. Monetary policy is usually pegged against a nominal anchor. In our sample Norges Bank has basically used two different nominal anchors, a fixed exchange rate and a flexible inflation target. There is not much literature on the subject, but we know from research done in the US that the term spread has had predictive power under different kind of monetary regimes (Eijffinger et al. 2000). The predictability seems to vary over time and seems to be connected to the monetary authorities' credibility.[3] Federal Reserve's goal is to promote effectively the goals of maximum employment, stable prices and moderate long-term interest rates.[4] This is very similar to a flexible inflation target.

A flexible inflation target tries to minimize a loss function (Meyer 2004, see comment by Lars E.O Svensson). The relative weight the central bank puts on respectively inflation gap and output gap will affect the influence that monetary policy have on the term structure. If the central bank puts more weight on the short-term output gap it will have less influence on the output gap in any given period. This is a consequence of the fact that monetary policy cannot influence real economic activity in the long run. Since more weight on the output gap leaves the central bank with less power to affect the inflation gap, the future term spread will become less sensitive to changes in monetary policy because of the link between monetary policy and the term spread (Eijffinger et al. 1998).

[3] Estrella 2005 Yield curve faq: http://www.newyorkfed.org/research/capital_markets/ycfaq.html#Q3
[4] Federal Reserve's Monetary polic and the economy: www.federalreserve.gov/pf/pdf/pf_2.pdf

TABLE 2.1: MONETARY REGIMES IN NORWAY

Time period	Monetary regime
1978 – October 1990	Fixed trade weighted exchange rate
October 1990 – December 1992	Fixed exchange rate against ECU
December 1992 – May 1994	Floating exchange rate
May 1994 – March 2001	Stable exchange rate against other European exchange rates
March 2001 (January 1999) -	Flexible inflation target on 2,5% and floating exchange rate

Source: Norges Bank.[5]

Although Norges Bank officially changed the monetary policy towards an inflation target in March 2001, it is a common opinion among economist that Norges Bank really changed to an inflation target when current governor of the central bank Svein Gjedrem took office in January 1999.[6]

Besides the discussion on what nominal anchor to use, it is also interesting to look at in what degree the monetary policy is conducted using rules or discretion. The degree of flexibility in monetary policy's target is likely to influence both ends of the term structure. Today Norway has a "policy mix" where the inflation target is 2.5% in a medium-term horizon. The fiscal policy is restricted by 'handlingsregelen'[7]. These are explicit rules, but both gives room for judgment.

[5]Norges Bank 2004: Norske Finansmarkeder – Pengepolitikk og Finansiell stabilitet: http://www.norges-bank.no/upload/import/pengepolitikk/historikk.pdf

[6] Inge Furre lecture in Pengemarkeder og Bankvesen 2006.

[7] 'Handlingsregelen': The Norwegian government is supposed to use only the real return of the Norwegian Pension fund. That way it will exist forever. Expected real return is 4 %. The amount is also adjusted after business cycles; if tax income i.e. are higher than what has been calculated as the trend level then the politicians aren't suppose to use as much as the 4% rule allows. The volatility of the income related to the oil sector will not have an effect on the Norwegian government budget in such a scenario.

Since the different kind of monetary policies react different to economic conditions, there is no doubt that the effect on the term structure will vary depending on the monetary regime. Long-term interest rates reflect the markets anticipation of a natural interest rate level in the future. The central bank can try to guide the market's expectations through communication and publishing their thoughts and anticipation for the future. The influence the monetary authorities will have on the market depends on its history and credibility.

2.3.1 Can monetary policy influence both ends of the term structure?

It is often assumed in current monetary regimes that central banks can only control the short end of the term structure. The effect on the long end of the term structure is much more difficult to anticipate. A tightening of the monetary policy will raise short-term interest, but will have less effect on long-term interest rates. Long-term-interest rates might even fall. When a monetary tightening occur the market usually expect less inflationary pressure in the future and might even expect lower long-term interest rates as a result of a more expansionary monetary policy in the future. This will flatten or even invert the term structure. After some time the contractive monetary policy will have a contractive effect on real output in the economy (Isachsen et al. 1998).

TABLE 2.2: VOLATILITY UNDER DIFFERENT MONETARY REGIMES IN NORWAY

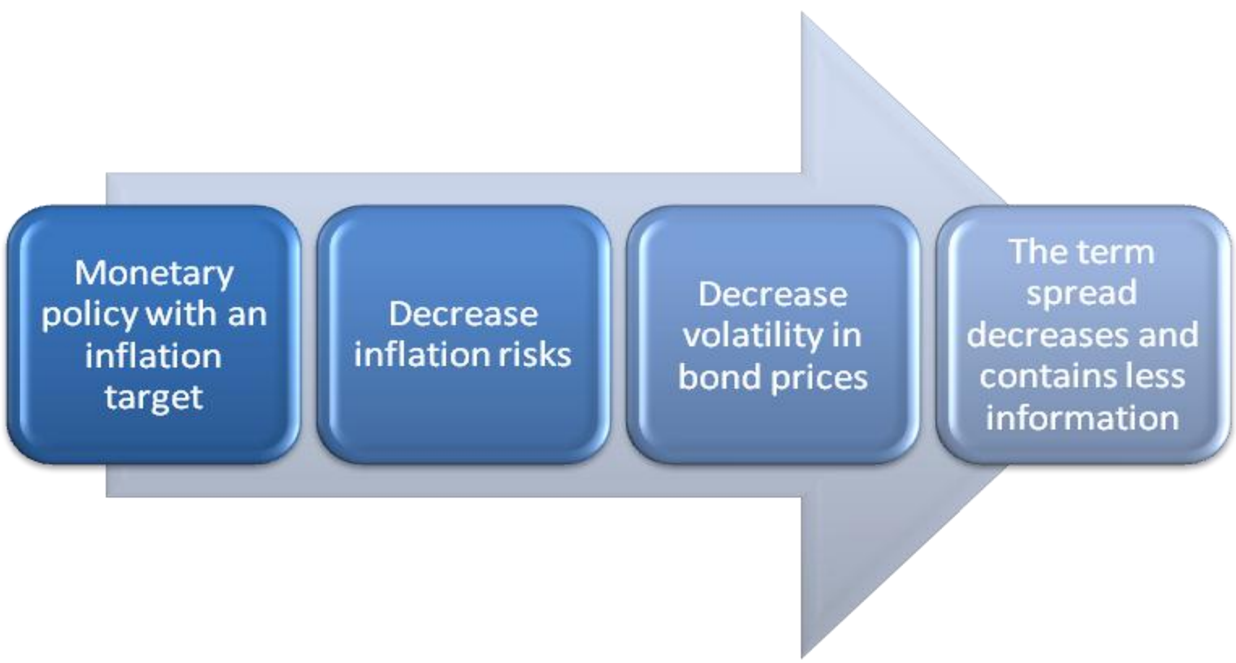
Monetary regime and time period	Average term spread in percent	Average volatility in percent	Number of months
Fixed trade weighted exchange rate. (January 1986 – September 1990)	-1.667	0.379	57
Fixed exchange rate against ECU. (October 1990 – November 1992)	-1.823	1.358	26
Floating exchange rate. (December 1992 – May 1994)	-0.815	1.828	17
Stable against other European currencies. (May 1994 – December 1999)	1.302	0.643	56
Flexible inflation target (January 1999 -)	0.051	0.522	111
The whole period (January 1986 – April 2008)	-0.072	0.388	267
Flexible inflation target (2003 – April 2008)	1.220	1.042	51

Note: Average volatility is measured as standard deviation of the available daily term spreads between ten-year government bonds and three-month NIBOR .
Source: Authors own calculations

Recent research indicates that monetary authorities can control and influence the long end of the term structure if the inflation target is reliable.

"No volatility, no forecasting power for the term spread" is the headline in the Monetary Trends issue of April 2008, published by the federal reserve bank of St.Louis.[8]. This article claims that there has been a recent disconnection between the term spread and the real growth of the economy in the US. According to the article the explanation is less volatile long-term inflation expectations.

FIGURE 2.1: INFLATION TARGETING AND THE TERM SPREAD



[8] M.Guidolin & A.K. Rodean: Monetary Trends 2008, Federal Reserve Bank of St.Louis: http://research.stlouisfed.org/publications/mt/20080401/cover.pdf

Monetary policy plays an important part in theories surrounding the term spread. If the inflation target adopted by the monetary authorities is reliable, it will decrease the volatility in the yield of long-term bonds. Volatility of the term spread can be seen as a way to quantify risk in long-term bonds. The volatility in the term spread is a result of the markets inflation expectations. When the long-term inflation expectations change, the bond prices will be revised. When future inflation is insecure and the market often revise their expectations bond prices will have high volatility. The market will then demand a risk premium because of this volatility.

If you assume that inflation risk decline independent of business cycles, lower risk will lead to lower volatility. This will in turn lead to a lower term spread and less information. If this is correct, one should expect a decrease in the explanatory power of the US term spread over real economic activity. The term premium is a risk premium compensation for inflation risks. It's only natural that this premium declines when risk disappears.

A simple comparison of the volatility under different monetary regimes in Norway, gives interesting results. Unfortunately there aren't any daily three-month Treasury bills offered by Norwegian central bank until January 2003. We experimented by using the three-month Nibor rate instead of the Treasury rate to assess the volatility in the Norwegian term spread. The three-month Nibor is quite different from the Treasury bills and we don't want to conclude anything from these results.

In the bottom row in table 2.2 we present the result using daily Treasury rates from 2003. We find the average term spread and volatility from January 2003 until April 2008. As in the article, we have computed these numbers using daily yields. The average term spread and term spread volatility in this period is almost the same as the results in USA from 1995 to 2007.

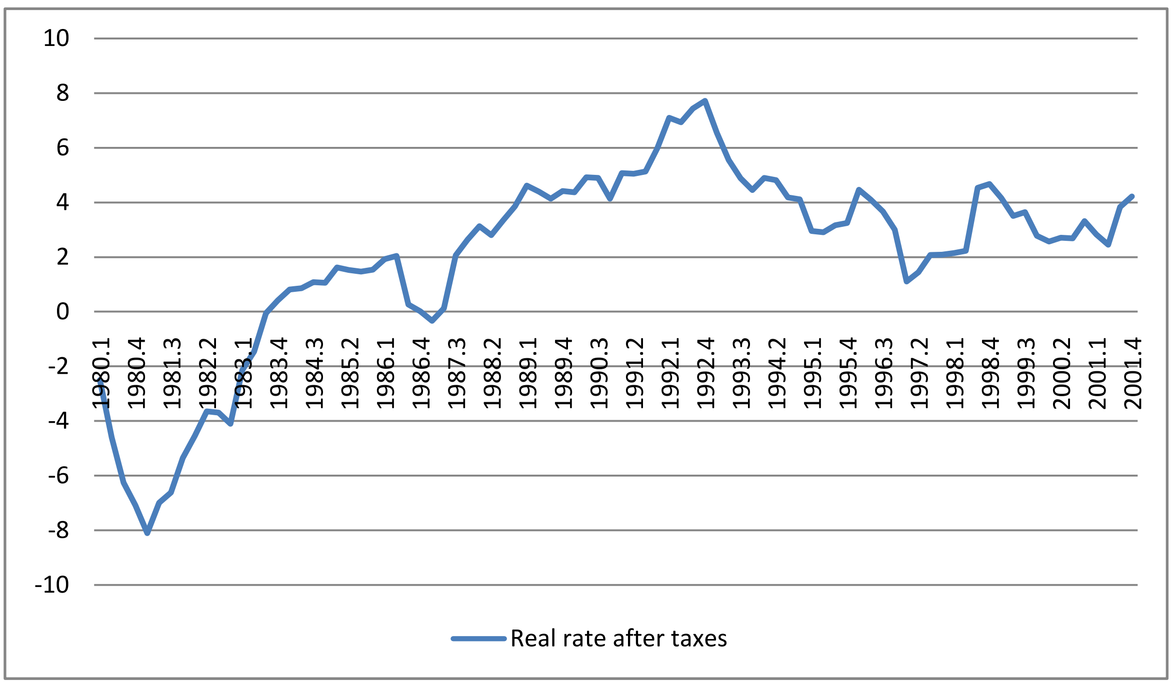
The low volatility in the term spread might indicate that the Norwegian and US central banks successfully have anchored inflation expectations. Because of this, the predictive power of the term spread might be reduced.

2.3.2 Monetary policy and country specific factors in Norway late eighties and early nineties.

Deregulations, credit growth and expansive monetary policy during a boom

As a measure of the state of the monetary policy it is common to use the real interest rate. Until September 1985 the Norwegian interest rate was politically fixed at level below the Nibor rate. Although the interest rates were allowed to float freely from 1985 it stayed below the Nibor rate until the end of 1988, mainly due to political opposition to increase interest rates. At the same time the Norwegian financial market was deregulated and liberalized. This led to a huge boom in credit volume. By the mid eighties the Norwegian economy boomed. As you can see from figure 2.2 and 2.3 the real interest rate was low and even negative and credit volume exploded.[9]

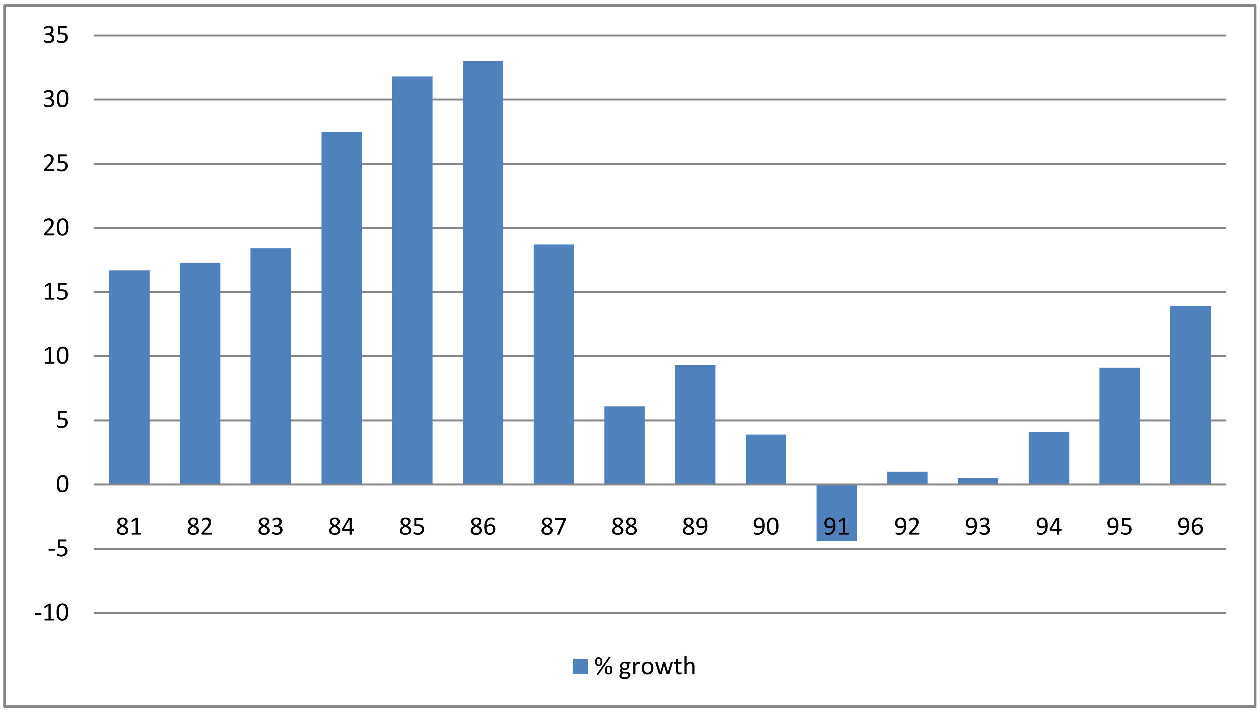
FIGURE 2.2: REAL INTEREST RATE AFTER TAXES



Source: 'Kredittilsynet'.

[9] Kreditttilsynet: Erling Steigum: "The Norwegian Boom-Bust Cycle and Bank Crisis Revisited" , seminar on financial crisis Oslo September 11, 2002

FIGURE 2.3: GROWTH IN NOMINAL LENDING BY PARENT BANKS



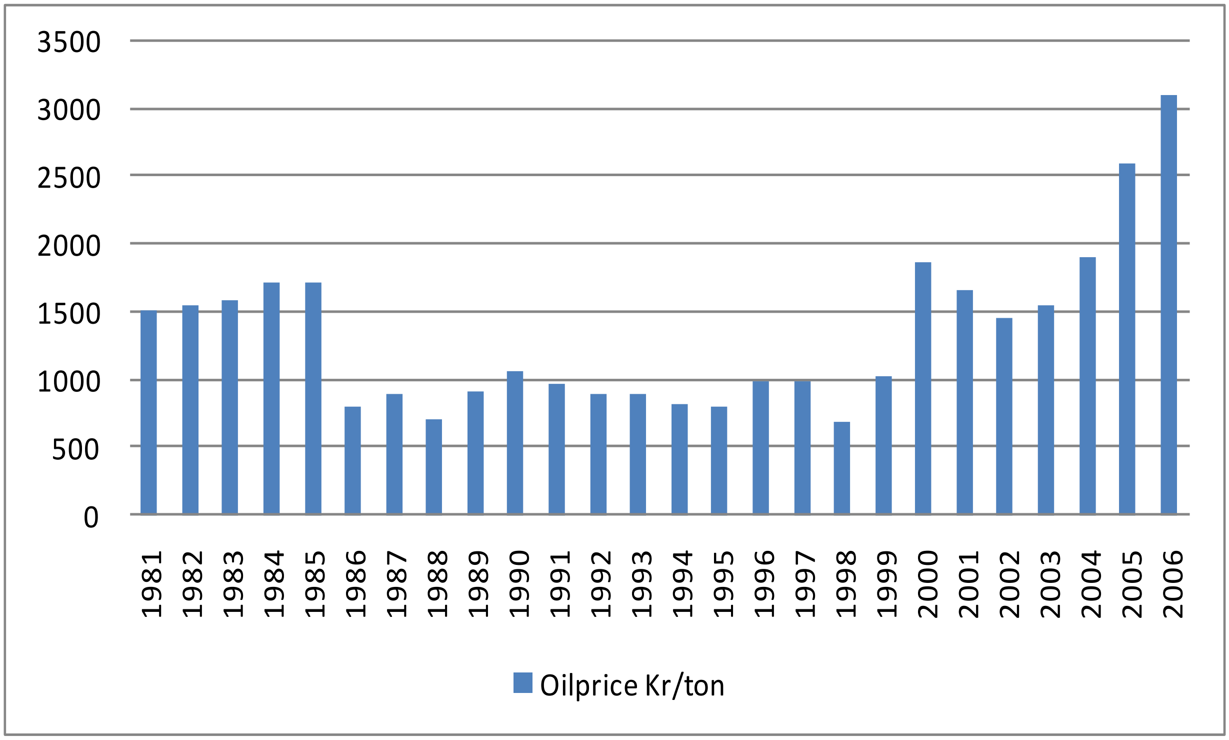
Source: 'Kredittilsynet'.

The oil price collapses

By the eighties the oil sector was an essential part of the Norwegian economy. The OPEC 1 and OPEC 2 had made future income expectations from the oil sector bright. The Norwegian economy bloomed together with the good economic times internationally. But in 1986 the oil price collapsed (see figure 2.4). The price of oil dropped from over 30 US dollar a barrel to under 10 US dollar. For most countries, not exporting oil, a lower oil price is good news. However, for Norway it was the beginning of an economic downturn. Government tax income from the oil industry dropped 69 billion in 1985 to 14 billion Norwegian kroner in 1988.[10] [11] Capital started flowing out of Norway. The central bank had to provide the bank market with liquidity to avoid an increase in the Nibor rate. By May the banking sectors debt was as high as 70 billion kroner.

[10] Teknisk museum: http://www.tekniskmuseum.no/no/utstillingene/Jakten_oljen/historie.htm
[11] To avoid a similar problem today, Norway uses a policy rule called 'handlingsregelen' explained earlier.

FIGURE 2.4: OILPRICE KR/TON



Source: Norges Bank

Bank crisis, house market crash and contractive monetary policy during a recession.

The huge debt increase left the Norwegian banks very exposed and vulnerable when the international business cycles turned at the end of the eighties (Klovland 1999). In 1988, the real estate market also began to fall. "Bad banking"[12] had resulted in a price increase in the real estate market, which made it easier to obtain loans. When business cycles turned and the recession started in 1988 the real estate prices also fell. Over a few years it fell about 30% in private real estate market and corporate real estate fell as much as about 50%. The banking sector got the highest losses in the corporate sector. This was the beginning of a banking crisis in Norway (see figure 2.5 and 2.6).

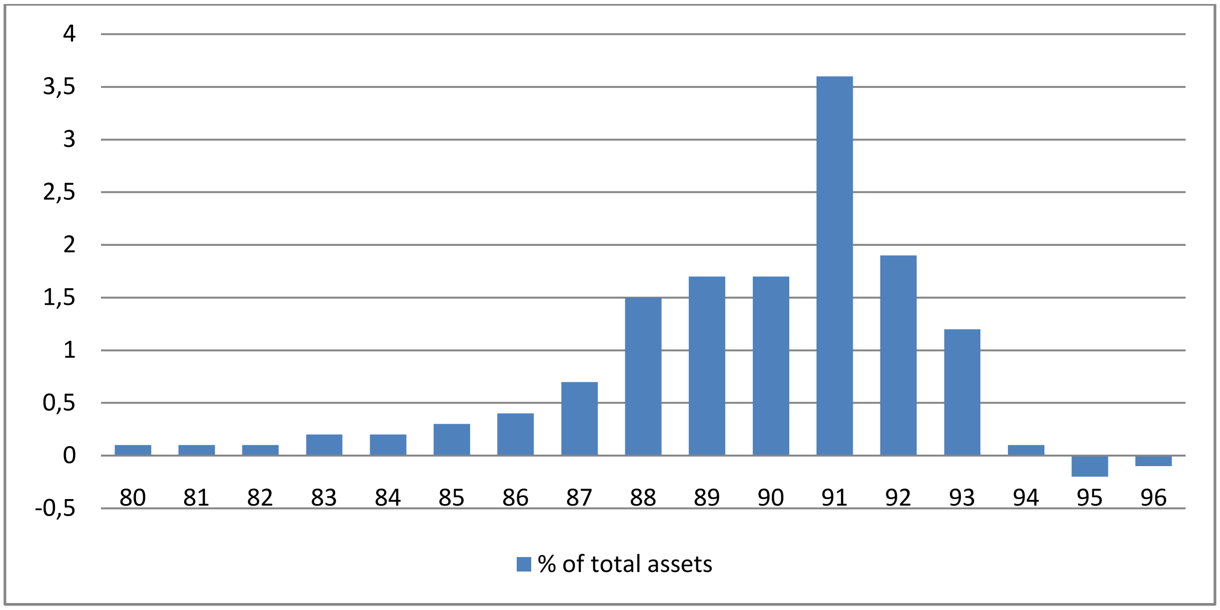
[12] Bad banking: Banks giving loans to people/companies that aren't credit worthy.

FIGURE 2.5: PERCENTAGE CHANGE IN REAL ESTATE PRICES IN NORWAY

Source: Norges Bank

The crisis in the banking sector started in 1988 and didn't end until 1993. Its peak was in 1991 when two of the largest banks in Norway lost all its capital and the government acted as a lender of last resort and took control over the banks. Before 1991 there were mostly small regional banks that collapsed (Vale 2004).

FIGURE 2.6: TOTAL BANK LOSSES IN NORWAY



Source: Norges Bank

In the eighties Norway had a fixed trade weighted exchange rate and from 1990 to 1992 the exchange rate was fixed against the ECU. The attempts to fix the exchange rate put some restraints on the monetary policy. Under the recession late in the eighties and bank crisis in 1991-92 the central bank was forced to conduct a contractive monetary policy with high real interest rates in order to keep the exchange rate close to the exchange rate target. During the bank crisis German monetary authorities led a very tight monetary policy due to the reunion between East- and West-Germany. The German currency had the largest weight in Norway's fixed trade weighted exchange rate, so Norwegian monetary policy depended on German business cycles. In this period the business cycles in Norway were very different and this made Norwegian monetary policy pro-cyclical and destabilizing.

Because monetary policy is such an important part of the term structure theory as a predictor of business cycles, we don't expect the first period in our sample to give very much information. This will affect how we treat our data material. We will look at different subsamples and see how the predictive power of the term spread gives information within different samples.

2.4 A comparison to other leading indicators

An assessment of an indicator for business cycles should consider its characteristics in comparison to other indicators which are similar in its relationship to the underlying business cycle. Leading indicators are series which normally should shift direction in advance of the development in the business cycle (Conference Board 2001). The term structure should thus be expected to invert (that is the term spread should become negative) in advance of a recession.

Several criteria are used when assessing the characteristics of an indicator. Sorensen & Whitta-Jacobsen (2005) evaluated several macroeconomic variables' indicator characteristics with respect to growth in GDP. The indicators were examined along the following dimensions: volatility (measured by standard deviation), correlation (measured by covariance and the coefficient of correlation), and persistence (measured by the coefficient of autocorrelation).

With regards to the cyclic volatility, the term spread on government bonds is to a large degree controlled by the monetary authorities in a given country depending on the monetary regime. It is thus a more stable series than investments or stock market indices. The stability is a strength, because the number of false signals will reduce as the stability increases. On the other hand, it is to some degree conditioned by the monetary authority's correct perception of real economic activity to actually be a true signal.

The term spread should in theory be positively correlated with growth in GDP with zero and –x lags, and negatively correlated with growth in GDP +x lags. This is given that the long end of the term structure is relatively constant. The strength of the term structure in this respect seems to be the consistency of the leading correlation compared to other leading indicators (Gerdrup et al. 2006). This consistency is also confirmed by the probit-models examined by Dueker (1997) in which the term structure seems to be the best predicator of GNP growth as the horizon increases. This is compared to the composite leading indicator and the stock market on US data. Gerdrup et al. (2006) found positive correlation between the term structure and GDP growth on Norwegian data from 1993 to 2005. In addition, the term structure had a more leading capacity than the short-term interest rate.

Another point which strengthens the predictive power of the term structure is that it doesn't seem to rely to a large degree on the strength of the signal. Estrella & Trubin (2006) finds that as long as the signals are persistent and negative, the term structure seems to be a reliable predictor of US recessions since 1950. Furthermore, the probit model studied by Estrella & Trubin (2006) doesn't depend on whether the signal is driven by long or short end movements. Together these findings justify studying inversions at a monthly or quarterly basis. This suggests some degree of positive autocorrelation in the term spread in order to observe an inverted term structure on a monthly or quarterly basis preceding the recessions. This is also conditioned by the monetary policy conducted.

Practical considerations such as the relative high frequency of observations and the fact that these are easy to interpret also speaks in favour of the leading characteristics of the term structure. In addition, the observations are not subject to subsequent revisions. This reduces the risk of the observing false signals.

The theoretical foundation for the relationship was described in section 2.1. However, the lack of a single explicit model for the relationship may weaken the strength of the established empirical results. That is, the theoretical explanations tend to be heuristic (Estrella 2005a). Compared to other leading indicators such as stock indices, industrial productivity or nominal interest rates that easily fit in theoretical macroeconomic models of business cycles, the explanations regarding the term structure tend to be based on the specific empirical results found. However, there have been successful attempts to study the term structure in explicit models, in example Estrella's (2005a) dynamic theoretical rational expectations model. This suggests that the theoretical foundations rely in part on the monetary policy conducted in a given country.

Other aspects of the theoretical relationship are associated with a larger degree of uncertainty. If the short-term interest rate is expected to increase because of higher expected inflation in the future and not as an expectation of increased economic growth, the term structure will be impaired as a leading indicator. In addition, the risk premium might be time-varying. Consider an investor exposed to the risk of achieving a lower than expected real rate of return on bonds with long maturity. This can happen if the inflation during the period is greater than expected ex ante, and cause the long-term interest rate to increase as the investors become more uncertain about the future rate of inflation, and weaken the relationship (Gerdrup et al. 2006).

The OECD criteria for using a leading indicator can give further insight into the leading properties of the term structure (Nilsson 1987). The economic significance is well covered under its relationship to real economic activity. This should also satisfy the breadth of coverage into economic activity for a given country. With observations on monthly or quarterly basis, there should be absence of extra cycles (or so called false signals). However, one could object that the correlation with real GDP growth is too weak and therefore unsatisfactory according to the OECD criteria. By examining the probit models studied by Estrella & Trubin (2006) this criteria could be relaxed, because the strength of the signal didn't affect the predictive ability of the term structure.

For these reasons the term structure can have good leading properties, and even better and more leading characteristics than other indicators, even though the theoretical foundation is not obvious and the monetary policy's role seem to influence the information content of the indicator.

2.5 Typical features of the Norwegian business cycles

When studying the relationship between the term structure and the business cycles of Norway, it is necessary to take a closer look on what factors that is unique to the Norwegian business cycles compared to business cycles in other countries. These could affect our results and cause them to deviate from studies on other countries.

For a small country like Norway, it is expected that the country is a price taker when it is not dominant in any particular export market on world basis. The main source of variations in real economic activity in the period from the end of the 1950s to the end of the 1970s was therefore from foreign cycles in demand for Norwegian exported products (Wettergreen 1978). This influenced the Norwegian export-production and prices. The effects of international interest and exchange rates were blocked through heavy regulation. A part of this was due to the fixed exchange rate policy in the period.

During the 1980s the business cycles became more severe than both the previous Norwegian cycles, and the cycles of the trading partners of Norway (Johansen & Eika 2000). This was due to two structural changes of the Norwegian economy during the 70s and 80s (Klovland 2007):

1. The heavy investments and the growth of the oil sector following the discoveries of oil fields during the 70s caused the real economy to be more dependent on the price of raw oil. This resulted in asymmetric development of the Norwegian business cycles compared to the European cycles. This happened for two reasons. First, an increase in the oil price has a negative effect on the global cycle. Second, a negative effect on the Norwegian cycle on short-term (due to reduced foreign demand), but a strong positive effect on a longer term due to the increased profitability of investments in the oil sector.

2. The substantial deregulations of the credit market during the 1980s, in combination with the fixed exchange rate regime conducted, contributed to the reinforcement of the business cycles in the period. First, the deregulations reinforced the international expansion which took place from about 83-85. Second, the fixed exchange rate regime

required a relatively high interest rate during the recession at the end of the 80s and start of the 90s, something which reinforced the recession.

Together these structural changes contributed to the asymmetric business cycles of Norway during the 1980s.

The relationship between the oil price and macroeconomic variables has been shown to be symmetrical; an increase and decrease in real oil price has opposite effects on real GNP growth (Mork 1989). The study conducted by Johansen & Eika (2000) finds that the oil price and investments in the oil sector exert the largest pro-cyclical influence on the Norwegian business cycles during the 1990s. This result is likely to be present if the period is extended after 2000, considering the investments in new searches and development of existing extraction facilities still are substantial. On longer term the oil sector could be expected to contribute less pro-cyclical, as the investments are reduced and the sector shifts to a pure production sector.

The deregulations of the 80s were a period specific characteristic, and are thus not a relevant factor for today's business cycles. The fixed exchange rate has been abolished as target for the monetary policy in favor of other regimes, an today the monetary policy target is a flexible inflation target.

The more traditional international impulses influencing foreign demand are still present. These manifest themselves through international product markets (through export production and export prices) and international financial markets (interest and exchange rate). The Norwegian de-regulations of the credit market in the 80s, other countries de-regulations and increased international capital mobility give reason to believe in increased influences from international financial markets in recent years. The study conducted by Johansen & Eika (2000) finds that the product markets contributed counter-cyclical, while the interest and exchange rate contributed pro-cyclical during the 90s.

Based on this, a perception of the monetary policy targets as independent of global (and trading partner's) business cycles is flawed. The US federal funds target rate should influence the global business cycle, thus influencing the monetary policies of US trading partners with +x lags. The Norwegian monetary policy should therefore recognize both the US target rate, in addition to its main trading partners target rates. It would therefore be necessary not to deviate too much from the Euro rate over a longer period, as long as a stable exchange rate is the target. In example, the tight monetary policy of the re-unified Germany during the 90s, and the fact that the Norwegian krone was tied to a basket of European currencies, did not allow much room for flexibility in setting the target rate for the Norwegian Central bank at that time. Large deviations from the German interest rate would result in a depreciation of the Norwegian Kroner. Therefore the central bank was forced to lead a pro-cyclical monetary policy. This dilemma existed until 1999 when inflation targeting was pursued (Klovland 2007).

A clear result from this mechanism should be that the US federal funds target rate influence the Norwegian business cycle through the global ones. And the Norwegian interest rate cannot deviate substantially from the level of the German interest rate on longer term, even though Norway have country specific factors that cause such deviations necessary in certain periods to avoid a pro-cyclical monetary policy. However, it will be a well-balanced consideration, since large exchange rate fluctuation would make the exporting industries of Norway vulnerable to foreign competition through the exchange rate mechanism.

3. Data

In this section we present details on the data which we use to estimate the models we use in this thesis. Below we have listed some points that we will report regarding the data material:

- ✓ Where the data is available. Internet links are listed as a reference to the reader.
- ✓ An explanation of the variables, and how they are connected to our models.
- ✓ How we have edited the data. In example, some of the data material where reported monthly and we needed to transform it into quarterly data to fit our models.

Norwegian Treasury bills

The Norwegian Treasury bills with maturities from three-, six-, nine- and twelve - month were obtained from a study conducted on the Norwegian interest rates conducted by Jan Tore Klovland and Oyvind Eitrheim (2007). The data material was reported monthly; in order to get it quarterly we have taken the arithmetic average of the three observations in every quarter. There wasn't a market for Norwegian Treasury bills until 1985. Furthermore, this market took some time in order to become efficient, and truly reflect all market factors. This limited our sample accordingly.

Norwegian Treasury bonds

The Treasury bonds were obtained from the web site of Norges Bank. We use maturities of three, five and ten years.[13] Because the data material only was available in monthly and yearly observations, we have taken the average of the three monthly observations in a quarter to create the yield on quarterly Norwegian Treasury bonds. We use these Norwegian Treasury bills and bonds to calculate the different Norwegian term spreads, in the short and long end respectively.

[13] Norges Bank: http://www.norges-bank.no/Pages/Article____41607.aspx

Norwegian GDP

The Norwegian GDP was obtained on the website of Statistics Norway (SSB)[14]. We use a GDP in fixed 2005 – prices and the data material is quarterly and seasonally adjusted.[15] We use GDP as a measure of real economic activity.

Oil price and oil investments

We got the oil price from Norges Bank's 'troll-database'. The oil price is measured in USD/barrel unless otherwise specified. We use the price on Brent blend oil. Contact Norges Bank for data.

Oil investments were found on the website of Statistics Norway (SSB).[16] In this variable we include "oil-search and oil-drill", "platforms, riggs and modules", "extraction of oil and gass, including services" and "oil-refinement, chemical and mineral industry". We add up these four variables to get the total oil investments. Both oil price and oil investments are listed in quarterly data. We use the oil investments to control for the influence of the oil sector, in the relationship between the Norwegian term spread and real economic activity. An alternative measure is the oil price, but as showed later, the oil investments seem to exhibit more information (or more useful information).

German Treasury bills and bonds

We got in contact with Eurostat, and they sent us the ten-year Treasury rates and one-year Treasury bills from Germany reported monthly. These were averaged into quarterly observations. Contact Eurostat or the authors for the data. Germany doesn't have any three-

[14] Norwegian name: Statisktisk Sentral Byrå (SSB)

[15]http://statbank.ssb.no/statistikkbanken/Default_FR.asp?Productid=09.01&PXSid=0&nvl=true&PLanguage=0&tilside=selecttable/MenuSelP.asp&SubjectCode=09

[16]http://statbank.ssb.no/statistikkbanken/Default_FR.asp?PXSid=0&nvl=true&PLanguage=0&tilside=selectvarval/define.asp&Tabellid=06164

On this website you choose this variables: " Oljeboring, oljeleting, olje- og gasrørledning" – " Oljeutvinningsplattformer, borerigger og moduler" – " Utvinning av råolje og naturgass, inklusiv tjenester" – " Oljeraffinering, kjemisk og mineralsk industri" month Treasury rate, therefore we had to use a one-year Treasury rate instead. This should not make the results qualitatively different and the interpretation will probably be similar. These interest rates might of course be affected by the reunion between East- and West-Germany in 1990. However, we don't see any large deviation in either the short-end or the long-end of the term structure in this period.

German GDP

We found the German GDP on the website of the Deutsche Bundesbank. The German GDP is in fixed prices and seasonally and working-day adjusted. The data material was already quarterly.[17] Both the seasonal adjustment and the break in the series following the reunification were edited by the Deutsche Bundesbank. The quarterly data at previous year prices are calculated as a chain-linked Laspeyres index (annual overlap). The time series covers West-Germany until 1990 and Germany as a whole up from 1991 where the figures for both territories are linked over the annual average of 1991.

US Treasury bills and bonds

We got the US ten-year Treasury bond rate and the US three-month Treasury bill rate from the Federal Reserve Bank of New York.[18] The interest rates were reported monthly so we took the average to create quarterly data.

US GDP

The US GDP was obtained from the bureau of economic analysis. The US GDP is given in 2000 chained US dollars and seasonally adjusted. The data was also given quarterly.[19]

[17] Germany GDP: http://www.bundesbank.de/statistik/statistik_zeitreihen.en.php?lang=en&open=konjunktur&func=row&tr=JB5000

[18] http://www.newyorkfed.org/research/capital_markets/ycfaq.html There is a link on this website to the interest rates.

[19] Bureau of economic analysis, GDp data: http://www.bea.gov/national/xls/gdplev.xls

4. Econometric issues

This part provides a general discussion of how the relationship between the term structure and real economic activity can be estimated, and the econometric issues that go along with such estimation. Following the empirical studies conducted on US and German data, the two hypothesis of this paper is that the term structure does not and does consist of information that influence the real economy of Norway, and hence its business cycles. To analyze this hypothesis we use a quantitative approach.

Our quantitative approach implies estimating structured equations based on the economic theory provided in part 2. In addition, we estimate reduced form equations to better describe the strength of the economic relationship between the real economy and the term structure. These analyses of course assume that there exists a causal economic relationship between the term structure and the business cycle. This assumption is flawed by the lack of a single correct theoretical explanation of the causal relationship as described in part 2.

Of more concern is monetary policy's role in the structured relationship. Estrella (2005a) argues that the weight of the term structure in the predictive relationship on output and inflation is a function of the monetary policy rule conducted by monetary authorities in its interest rate setting. Estrella suggests that the role of the term spread in the predictive relationship declines as the relative policy weight shifts towards inflation targeting. In this respect, the predictive power of the term structure cannot be structural. This evidence is consistent with models that allow for regime shifts in monetary policy.

The empirical evidence on the term structure finds that the predictive power exists on US data, even though inflation targeting have been the goal for monetary policy in some of the periods studied. Thus, there must be more to the relationship than the monetary policy rule. Moreover, given that expectations are incorporated in the interest rates, and that these to some degree correspond to the structure of the economy, other factors than monetary policy become likely to influence the real economy (Estrella 2005b). The dynamic rational expectations theory allow for the term structure together with other factors to predict output and inflation

(Estrella 2005a). Incorporating the expectations of the private sector shows that the term spread is the instrument through which the monetary policy influences the real economy (Eijffinger et al. 1998). A similar effect is obtained by modeling sticky prices on goods, a model in which rational consumers substitute intertemporally based on expectations (Hardouvellis & Malliaropoulos 2004). Thus, even though the term structure cannot be said to be structural with certainty, its predictive power justify the estimation of a structural relationship.

The models are developed on the basis of the appropriate general econometric models. These are adjusted to fit the analysis of our hypothesis better. These adjustments are based on the economic relationships described in part 2, together with correlations analysis where this is appropriate.

We estimate two types of structural models, referred to as the standard OLS model and Estrella & Hardouvelis OLS model. Both are estimated using OLS, but they differ in how the dependent variable is measured. The former measure GDP growth as annual quarterly growth, and the latter measure GDP growth as cumulative and marginal annualized quarterly growth. While the former use lagged values of the independent variables, the latter use current values of the independent variable to predict 'future' GDP development. We estimate the standard OLS model based on our perception of prevailing theory. The Estrella & Hardouvelis OLS model is estimated because it has been replicated by several other studies, and thus our results can be compared to other research more easily.

4.1 The assumptions

The structural models can be estimated by OLS multiple regression analysis. We use multiple times series models. This complicates the regression analysis, compared to a simple regression model. In order for OLS to produce unbiased and consistent estimates the following assumptions must be valid in a large sample:

1. Linearity, stationarity and weak dependence for $\{(\mathbf{x}_t, y_t) : t = 1,2,....\}$
2. No perfect colinearity.
3. Zero conditional mean and contemporaneously exogenous $\mathbf{x}_t$, $E(u_t|\mathbf{x}_t) = 0$.
4. Contemporaneous homoskedasticity, $Var(u_t|\mathbf{x}_t) = \sigma^2$.
5. No serial correlation. For all $t \neq s$, $E(u_t u_s|\mathbf{x}_t, \mathbf{x}_s) = 0$

In small samples it is also necessary to assume normality:

6. The errors are independent of $\mathbf{x}_t$ and are independently and identically distributed as Normal, $u_t \sim N(0, \sigma^2)$

In order to examine the strength of our results, it is necessary to consider the validity of the OLS assumptions. Most important are the assumptions regarding stationarity[20], serial correlation, homoskedasticity and normality (in small samples).

The reduced form models can be estimated by so called probit models. Wooldridge (2006), states that, under general conditions, the MLE is consistent, asymptotically normal and asymptotically efficient[21]. Thus, the standard errors and t-tests for the estimates are valid as when using OLS.

[20] which is present when assumption (1) is not valid, and the series are characterized by persistence. In such cases, the law of large numbers and the central limit theorem cannot be applied to sample averages (Wooldridge 2006).
[21] For a more detailed description of the assumptions needed see Wooldridge (2002) chapter 13.

4.2 Statistical tests

In order to test the two hypotheses regarding the term spread's information value and predictive power, it is necessary to conduct some statistical tests on our estimates. This includes t-tests on the coefficient estimates and F-tests to better compare the various models. In addition we perform more general statistical analysis on the regression models. The primary objective of these tests is to examine whether the OLS assumptions hold. If they hold, this will increase the strength of our results.

4.2.1 T-test

The objective of the t-test is to test the parameters in our models separately. More specifically, this means to test whether the independent variables influence the variations in the dependent variable. Based on the tests we can draw conclusions about the relationship between the two. The hypothesis for this study is that the term spread contains information regarding the real economic activity in Norway. Thus, rejecting null-hypothesis $H_0 : \beta_K = 0$ against the two-sided alternative $\beta_K \neq 0$ would imply that the term spread doesn't have a zero effect on real economic activity. The t-statistic is given by:

$$t_{\hat{\beta}_K} = \frac{\hat{\beta}_K - \beta_K}{se(\hat{\beta}_K)}.$$

The null hypothesis is rejected if $\left|t_{\hat{\beta}_K}\right| > c$ for a given significance level[22]. The same procedure applies in testing the probit estimates; the only difference is that we test the z-distribution.

[22] Or equivalent if the p-value is smaller than the significance level of the test, $P(|T| > |t|) < \alpha$.

4.2.2 F-test

In order to compare the different models, we perform tests of whether the independent variables together explain the variations in real economic activity. The F-test assess whether the unexplained part (SSR) of the model increase too much when the independent variables of interest are excluded from the regression. The model is called unrestricted when the independent variables of interest are included and restricted when they are excluded. The null-hypothesis for our model is that the independent variables together have no effect on real economic activity; $H_0 : \beta_1 = \beta_2 = ... = \beta_k = 0$ [23] against the alternative that at least one of the coefficients is different from zero. The F-statistic is given by[24]:

$$F = \frac{(SSR_r - SSR_{ur})/k}{SSR_{ur}/(n-k-1)}.$$

The null-hypothesis is rejected if $F > c$ for a given significance level[25]. This is a test of the overall significance of the regression. If rejected, the coefficients tested are said to be jointly significant. Due to the non-linear nature of the probit estimation, the usual F-statistic cannot be applied. Because we are primarily concerned with the predictive power of the term structure, we reason the z-tests in the probit-estiamtation are sufficient.

[23] The unrestricted model has $k+1$ parameters, and conditioned by the null-hypothesis k exclusion restriction to test.

[24] Where k denotes the numerator degrees of freedom, $df_r - df_{ur}$ and $n-k-1$ is the denominator degrees of freedom, df_{ur}. The special version of the F-test where we test whether none of the independent variables have an effect on y, can be expressed in terms of the R-squared in the following way: $F = \frac{R^2/k}{(1-R^2)/(n-k-1)}$.

[25] Or equivalent if the p-value is smaller than the significance level of the test, $P(|F| > |f|) < \alpha$.

4.3 The sample periods

Considering the changes in targets for the Norwegian monetary policy from the 80s and up until today, it would be interesting to divide the sample up in different subsamples. This is a trade-off between reducing the number of observations, and increasing economic information value. A substantial reduction in number of observations will reduce the reliability of the analysis, but the information in the smaller subsample may be more interesting. Taking this into consideration we divide the sample in to two subsamples:

1. From 1985 quarter one to 1996 quarter four.
2. From 1997 quarter one to 2007 quarter four.

The idea behind this breakdown of the sample is that the both periods contain characteristics that are special to that specific sample only, characteristics that affect the entire sample. The first period was a very turbulent period for Norway, which experienced the banking crisis and pro-cyclical monetary policy (see section 2.3). In addition, the state of the Norwegian economy was too some degree tied to the German, which undertook a structural change with the reunion in 1990. In the second period, the Norwegian monetary policy shifted to inflation targeting as its primary target in the first quarter of 1999 unofficially. The last period is also associated with increased capital mobility and contagion, which affects all the countries in this study (Cholette 2007). These characteristics make a comparison of the results from the two subsamples a convenient way to study i.e. whether the targets for the monetary policy influence the information value for the term structure in Norway. If the primary hypothesis of this study was how monetary policy affect the information content in the term structure, a natural division of the subsamples would be according to the different monetary policy rules. We reason that separating the sample according to our dates will allow us to study the information content in the term structure during a stable period with few country specific factors that can influence our estimates.

5. A structural model – the standard OLS model

In this part we develop and present the standard OLS model. We do this by a preliminary description of a general model. This is adjusted to fit our perception of the prevailing theory and the correlations present below. Finally, the results are presented.

5.1 A general model

The hypothesis we want to study, implies that one factor (term spread) influences another factor (GDP). The hypothesis can therefore be described as how the variations in one explanatory variable X influence the variations in one dependent variable y. Due to the nature of the dependent variable, there is the possibility of other factors influencing the dependent variable which the model should control for. In addition, the effect of the independent variables on the dependent variable might be non-contemporary, as we are using time series data. Our theoretical relationship can best be described by a time series model with several independent variables which influence the dependent variable with lagged values. The model can be expressed the following way in general form:

$$y_{it} = \beta_0 + \beta_{1,1} X_{1it} + \beta_{1,2} X_{1it-1} + ... + \beta_{1,q} X_{1it-q} + ... + \beta_{2,1} X_{2it} + \beta_{2,2} X_{2it-1} + ... + \beta_{2,q} X_{1it-q} + ... + \beta_{K,q} X_{K,it-q} + u_{it} \quad (1)$$

,where $i = 1,2,..., N$ observations and $t = 1,2,..., T$. We study K explanatory lagged with *q* periods at time *t*. β_0 is a constant and u_t is the error term for observation i. This can be rewritten to

$$y_{it} = \beta_0 + \boldsymbol{\beta} \mathbf{x}_t + u_{it}. \quad (2)$$

, where $\mathbf{x}_t$ is the vector of K exogenous (or independent) variables lagged with *q* periods and $\boldsymbol{\beta}$ is the vector of corresponding coefficients. Since there are K exogenous variables and a constant, there are $K + 1$ population parameters in this model to be estimated. This representation is in line with Wooldridge (2006). The model contains the characteristics of a distributed lag model, where one or more of the explanatory variables are allowed to influence y_t with one or more lags. The dataset is balanced, meaning that the same variables appear in each time period. The multiple time series model allow us to control for several factors influencing the dependent variables, and understand the process that generate the data over time. In addition, the method justifies future predictions based on historical observations, assumed that they contain information about the future development of the dependent variable. Together these benefits results in a more dynamic analysis of the sample over time compared to a simple static regression model. Disadvantages are usually associated with violations of the assumptions listed in section 4.1.

5.2 The variables with correlation analysis

This part examines each of the possible independent variables relationship towards Norwegian GDP more carefully. To analyze the information content of the term structure we consider the Norwegian term spread itself, and in addition we consider controlling for the oil sectors influence and international influences. This includes investigating the possible theoretical relationships and correlation analysis where this is relevant for our model(s). Ultimately, this will be the basis of how the independent variables are represented in our models.We present the correlations between the independent variables and the dependent variable. The correlation analysis assumes that no third variable affect the estimated correlation between two variables, in order to be a good description of the relationship. This assumption is unrealistic in our case, and should be interpreted with caution. We present only the correlations between independent variables that are part of the final models we estimate. Possible third variables affecting the correlations we present are reported in appendix 12.1, but commented in the text.

5.2.1 Norwegian GDP

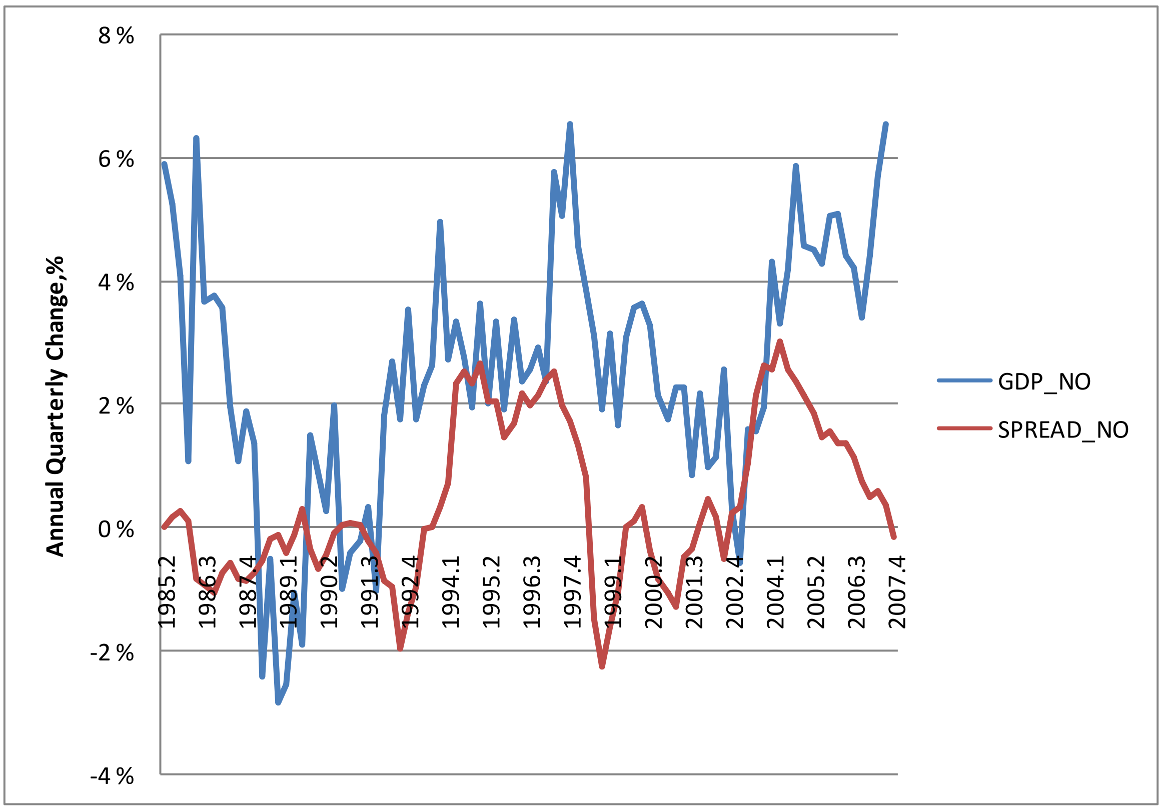
To study real economic activity we need some measure of how the level of economic activity changes over time. In addition, this measure should be reliable and computed relatively stable over time. Previous studies find the term spread to influence the GNP, GDP growth, consumption, investment and industrial production (Estrella 2005b). GDP measures the value of all goods and services produced within a country. Hence, the growth of GDP should describe how the real economy of a given country changes over time. This study uses the annual growth rate of quarterly GDP as a measure of real economic activity, defined as:

$$GDP\_NO = \frac{GDP_t}{GDP_{t-4}} - 1$$

, where t is one quarter of a year. This measure proves useful because GDP growth is also used to define recessions, which are used in the probit models. In addition, the annual quarterly growth is expected to be more stable than the quarterly growth or annual monthly growth, because some of the ‘random’ variations in GDP don’t influence the growth rate.

5.2.2 The Norwegian term spread

FIGURE 5.1: THE NORWEGIAN TERM SPREAD AND GDP



Source: Authors own calculations.

TABLE 5.1: CORRELATIONS BETWEEN NORWEGIAN GDP AND TERM SPREAD

Time-period # of quarters lagged *SPREAD_NO*	1985 - 1996	1997 - 2007	1985 – 2007
0 quarter	0.41	0.38	0.39
1 quarters	0.35	0.51	0.45
2 quarters	0.34	0.59	0.51
3 quarters	0.33	0.56	0.50
4 quarters	0.33	0.55	0.51
5 quarters	0.29	0.56	0.51
6 quarters	0.29	0.52	0.51
7 quarters	0.30	0.54	0.54
8 quarters	0.27	0.54	0.54
9 quarters	0.19	0.54	0.53
10 quarters	0.14	0.52	0.52
11 quarters	0.08	0.51	0.52
12 quarters	-0.10	0.45	0.47

Estrella & Trubin (2006) defines the term spread as the difference between Treasury securities of differing maturities. The combination that consistently seems to outperform other combinations is the difference between the constant discount rate on ten year government bonds minus the bond-equivalent yield on secondary market Treasury bills with three months maturity. The most accurate predictions are obtained with the securities whose maturities that are far apart from one another. Thus, we define the Norwegian term spread as:

$$SPREAD\_NO = i_{10years} - i_{3months}$$

, where i denotes the yield on the given Treasury.

The actual relationship between the Norwegian GDP growth and the term spread in our sample is presented in figure 5.1. An inversion seems to be followed by reduced GDP growth, but not with a consistent number of lags. The relationship also seems to be more consistent in the last half of the sample. From table 5.1 we choose to include the Norwegian term spread lagged with 2 quarters and 6 quarters.

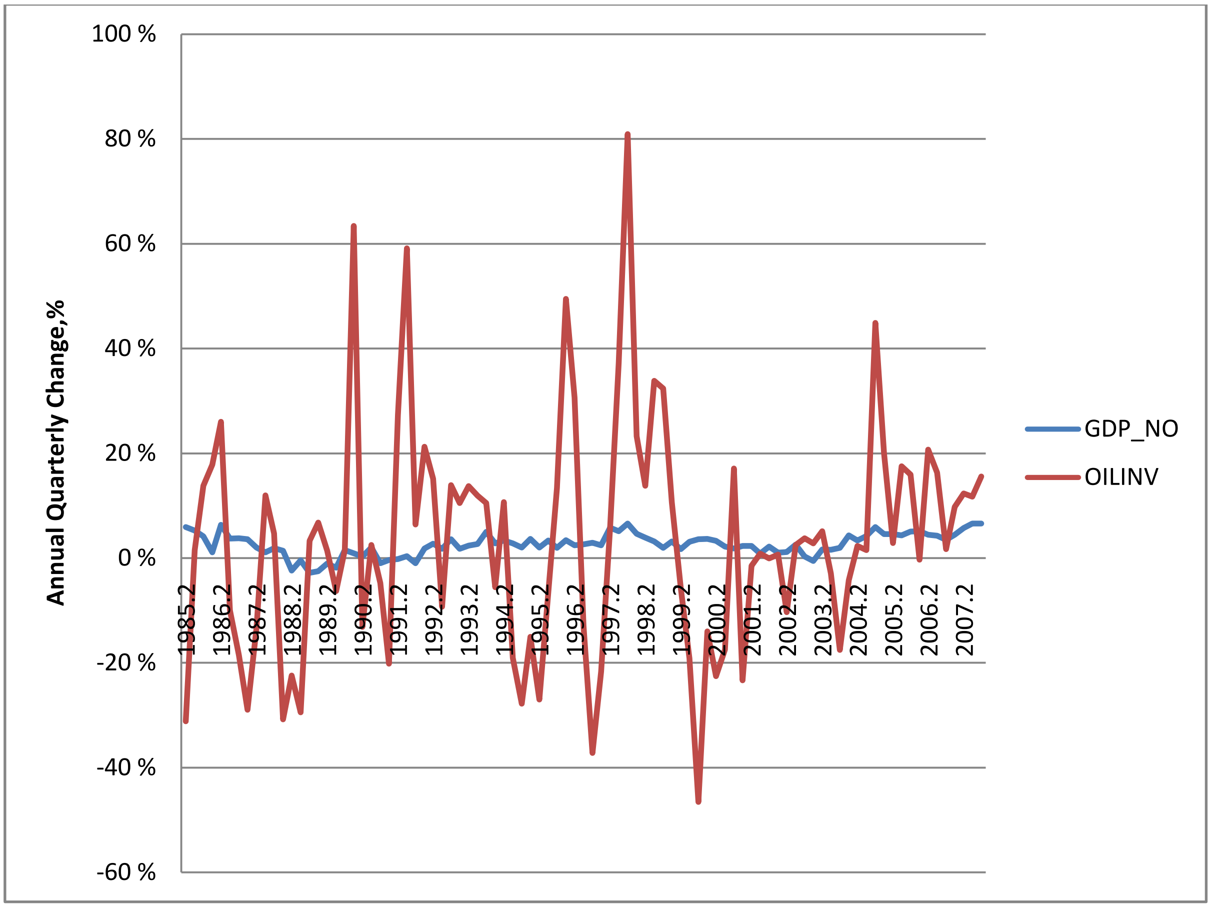
When we study correlations it's important to have in mind that they are dependent on how we measure the growth in each of the variables. In Gerdrup et.al (2006) they test correlation between the term spread and to different measures of real economic activity. First measured against the annual quarterly growth the term spread is positively correlated through all lags. Second measured against the output gap the term spread is positive with a high number of lags and becomes with only a few lags. We use annual quarterly growth which contains overlapping observations. Therefore we expect the lagged term spread to be positively correlated against the GDP measure.

We obtain correlations that are quite high. Indicating that a positive term spread change usually comes together with positive change in annual quarterly GDP growth. However, we don't get any useful information regarding what time lag the Norwegian term spread best predict the Norwegian business cycles. When looking at the correlations for the whole period it is clear that the term spread contain approximately the same amount of information whether the spread is lagged by four, eight or twelve quarters. That is, the range of the correlations are very small (min=0.39 and max=0.54).

Norway has a small and open economy and has a small bill and bond market. Because of this, the Norwegian term spread doesn't depend only on Norwegian business cycles. Instead, the term spread is to a large degree dependent on international financial markets. More specific, the long end is connected to the German interest rate, and the short end is independent (especially after 1998). If the Norwegian term spread actually reflects this, then the term spread needs to be interpreted with caution and will have periods when it won't be very reliable as a leading indicator.

5.2.3 The oil price and oil investments

FIGURE 5.2: THE OIL INVESTMENTS AND NORWEGIAN GDP



Source: Authors own calculations.

TABLE 5.2: CORRELATIONS BETWEEN NORWEGIAN GDP AND OIL INVESTMENTS

Time-period	1985 - 1996	1997 - 2007	1985 – 2007
# of quarters lagged *OILINV*			
0 quarter	-0.01	0.45	0.21
1 quarters	0.06	0.25	0.15
2 quarters	0.23	0.14	0.19
3 quarters	0.29	0.02	0.17
4 quarters	0.19	0.07	0.14
5 quarters	0.20	0.21	0.22
6 quarters	0.21	0.22	0.21
7 quarters	0.26	0.30	0.25
8 quarters	0.41	0.21	0.28
9 quarters	0.41	0.16	0.24
10 quarters	0.35	0.09	0.17
11 quarters	0.30	-0.03	0.10
12 quarters	0.34	-0.08	0.09

Following the atypical nature of some of the Norwegian business cycles described in part 2, it seems necessary to take into account the influence of the oil sector with regards to the Norwegian business cycles. Our model attempts to control for this influence. An approximation for this influence is the oil price and/or the level of investments in the oil sector. An increase in the price of oil is expected to influence the profitability of investments in the sector, thereby raising the demand for goods and services needed for seeking, extraction, processing and selling oil. This in turn raises the domestic production and GDP.

Figure 5.2 show that the annual growth rate of the oil investments seems much more volatile than the GDP growth rate. The correlations are positive throughout the sample, but a clear pattern of the size of the correlations with different lags does not emerge. This could be consistent with the different theoretical explanations that the effects of an oil price change exert different influence on GDP growth over time. This could also explain why the correlations are weaker for the oil price change[26]. The theoretical link between GDP growth and oil price does not provide a reasonable expected amount of lags. Nevertheless we choose to include lags of oil investments 0 and 8 in the model. These lags are thought to capture both short and long-term responsiveness of GDP to increased demand from the oil sector. The variable is defined as:

$$OILINV = \frac{INV_t}{INV_{t-4}} - 1$$

, where INV is the sum of all investments in the oil sector in quarter t. These include investments in drilling, searching, platforms, rigs and extraction of oil and gas, including services connected to these operations.

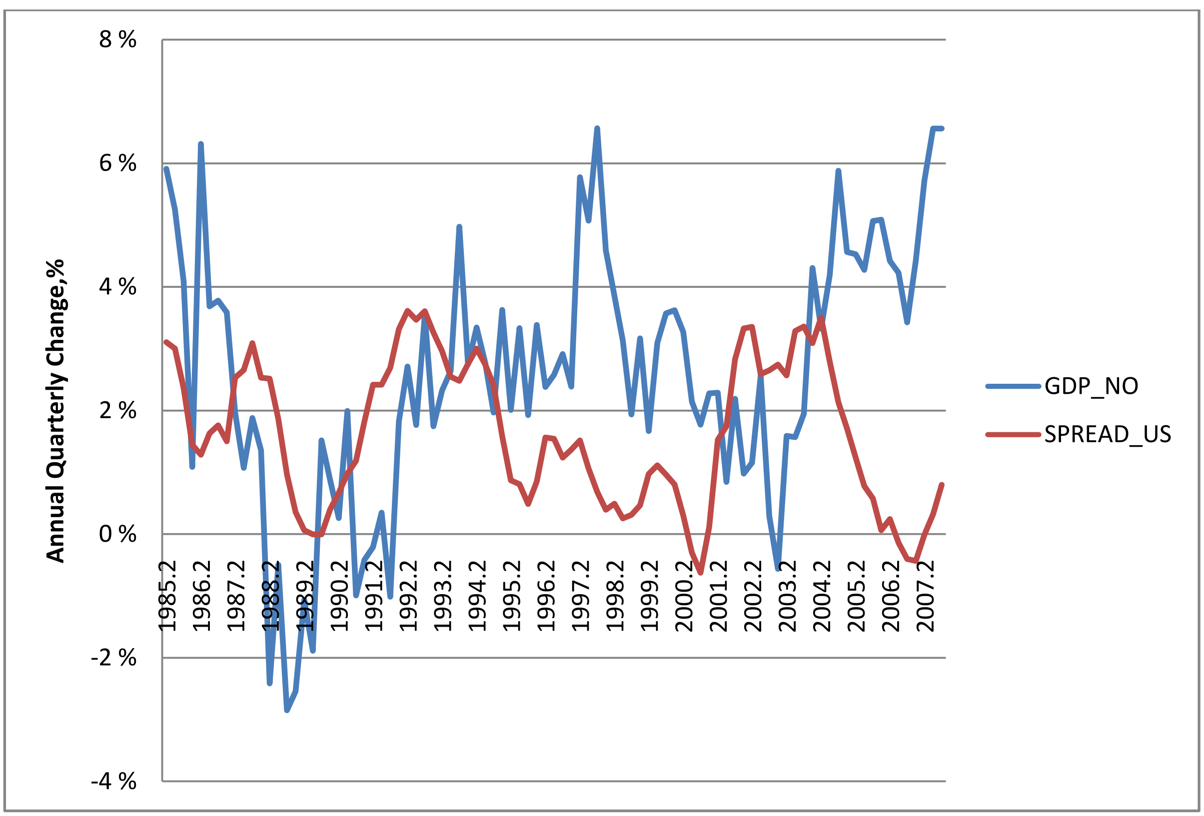
[26] See appendix 12.1 for correlations between annual quarterly growth in the oil price and *GDP_NO*.

5.2.4 International influences

Given some degree of dependency upon international product markets and international financial markets we consider several indicators that can exhibit some influence upon the Norwegian business cycles. The previous study of Bernard and Gerlach (1996), finds evidence that suggest that the German and US term spread influence domestic business cycles in several countries. It seems reasonable to believe that the indicators used in the study of Bernard and Gerlach to some degree also applies to the Norwegian real economy. In addition to the term spread, we explore the possibility of using the German and US GDP as sources of variations in international demand for Norwegian exports.

Influences from the US

FIGURE 5.3: THE US TERM SPREAD AND NORWEGIAN GDP



Source: Authors own calculations.

TABLE 5.3: CORRELATIONS BETWEEN NORWEGIAN GDP AND US TERM SPREAD

Time-period # of quarters lagged SPREAD_US	1985 - 1996	1997 - 2007	1985 – 2007
0 quarter	0.32	-0.40	-0.12
1 quarters	0.29	-0.30	-0.10
2 quarters	0.26	-0.21	-0.07
3 quarters	0.25	-0.15	-0.05
4 quarters	0.30	-0.06	0.01
5 quarters	0.38	0.06	0.09
6 quarters	0.43	0.12	0.13
7 quarters	0.39	0.22	0.15
8 quarters	0.42	0.34	0.21
9 quarters	0.35	0.46	0.24
10 quarters	0.29	0.56	0.26
11 quarters	0.22	0.66	0.28
12 quarters	-0.02	0.70	0.20

The significance of the American economy's influence over global economic conditions is well established in research on international financial markets. It would be only reasonable to concur that this also applies to the Norwegian real economy, because of small country characteristics. Because of the term spread's expectational qualities, we anticipate the term spread to manifest itself first in domestic GDP, and later in foreign economy's throughout the world. US GDP would therefore be positively correlated with Norwegian GDP with less lags than the US term spread. A comparison of table 5.3 and 12.2, reveal that the US term spread is more consistent with this pattern compared to US GDP.

Research on the term spread indicates that it can be used as a leading indicator and lead the GDP change by around four to six quarters.[27] We analyzed the correlation between change in the annual quarterly US GDP growth and change in Norwegian GDP and find highest correlation when we lag US GDP by zero to four quarters (see table 12.2 in the appendix). From this we could expect to find the highest correlations when we lag the US spread on Norwegian GDP by around four to ten quarters. There is of course some uncertainty in these estimates. Benedictow and Johansen (2005), who study the relationship between the GDP of the two countries on another longer period, find the highest correlation after one quarter.

The whole period give results that indicate that US term spread can be used as a leading indicator for Norwegian GDP (see table 5.3). We find the highest correlation after 11 quarters (0,28) in the entire sample, which is a very long time before the term spread to influences real economic activity. It is very uncertain that this is a reasonable time span for the effect. An interesting point is the considerable difference between our two subsamples. This result is exactly what we expected in our discussion earlier. The pro-cyclical monetary policy and the credit market liberalizations in the first subsample made the term spread inadequate as a leading indicator. Therefore it's very difficult to draw any conclusions from the sample period 1985-1996. However, the difference between correlations in the two subsamples is very interesting with regards to the differing predictive power of the term spread under different monetary regimes. In this analysis, the effect of monetary policy is not separated from the effect of credit market liberalization. So a conclusion about one or the other is difficult to put together; although the composite effect is present in the sample from 1985-1996.

However, the sample from 1997 until 2007 gives us very interesting results. The correlation is as high as 0.70 when we lag the US term spread twelve quarters on Norwegian GDP. This indicates that the US term spread contains information about future real economic activity not only in the USA, but also in Norway. This can make it useful for Norwegian monetary authorities to keep an eye on not only the Norwegian term spread, but also the US term spread. Remember that empirical research in the US usually finds that the term spread is inverted

[27] Estrella (2005b): Yield curve FAQ: http://www.ny.frb.org/research/capital_markets/ycfaq.html

around four to six quarters before a recession. This gives monetary authorities a leading indicator that signals business cycles a long time before the usual leading indicators.

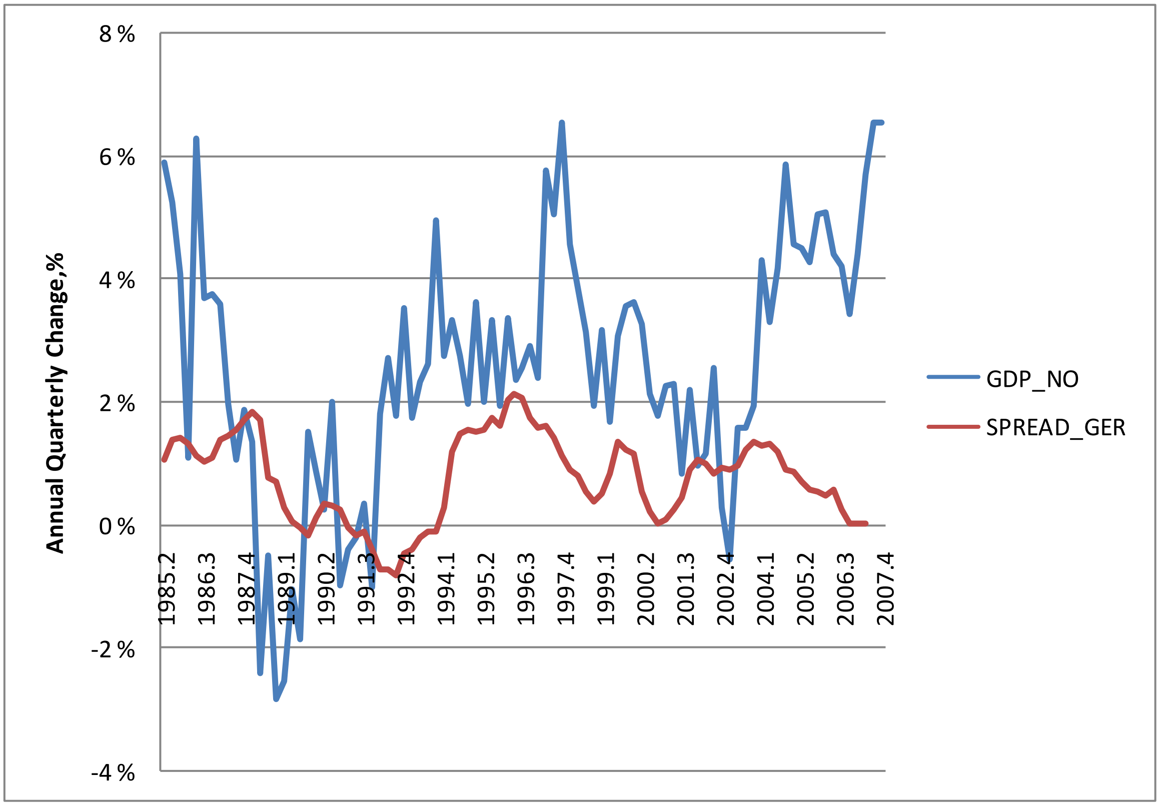
In the sample from 1997-2008 the correlations are negative at first. When we don't use any lags the correlation is -0.40. After that the correlations increases and peaks at twelve quarters with a correlation as high as 0.70. Intuitively these results indicate that there is a connection between the US term spread and Norwegian GDP, because the correlations move from negative to positive as we increase the lags used on the US term spread. It is reasonable that business cycles goes up and down, after a business cycle peak a through has to follow. If the term spread predicts recessions in the economy around four to six quarters ahead, it probably signals this sometime before the business cycle peaks. In other words, the term spread could decrease before the real economy hit its peak and start decreasing, and this can explain why we get a negative correlation when we don't use any lags.

We have to use as much as twelve quarters to get the highest correlation in the sample from 1997 to 2008. This is a little longer than expected, but the correlation is high and indicates that there is a connection. There can be several possible explanations for a long time lag. We have already mentioned the possibility that our time period seems to have more uncertainty in the number of quarters the Norwegian business cycles lag US business cycles. This might be due to some of the typical features of the Norwegian business cycle we discussed in section 2.5. In the spring 2008 when this thesis is written, we seem to see some of the same pattern. The sub-prime crisis seems to have sent the US economy into a recession. There has been turmoil in the international financial markets for some time. So far Norway have steered clear of the largest losses and the economy is still running at a high speed.

Considering this we choose to include the US spread with eight and twelve lags in the model, and denote it $SPREAD\_US$ from now on. The calculation of this variable is equal to the Norwegian term spread, combining securities with the same maturities.

The rationale for considering foreign GDP over foreign term spread would be that GDP is a more manifested or 'real' indicator than the term spread. Nevertheless, it seems that this don't apply to our sample. This can either be attributed to the domestic relationship between the US term spread and GDP, or the relationship between US and Norwegian GDP.

FIGURE 5.4: THE GERMAN TERM SPREAD AND NORWEGIAN GDP



Source: Authors own calculations.

TABLE 5.4: CORRELATIONS BETWEEN NORWEGIAN GDP AND GERMAN TERM SPREAD

Time-period # of quarters lagged *SPREAD_GER*	1985 – 1996 (47 obs.)	1997 – 2007 (42 obs.)	1985 – 2007 (89 obs.)
0 quarter	0,28	-0,04	0,21
1 quarters	0,13	0,16	0,18
2 quarters	0,03	0,31	0,17
3 quarters	-0,05	0,40	0,16
4 quarters	-0,12	0,45	0,15
5 quarters	-0,18	0,48	0,13
6 quarters	-0,19	0,49	0,15
7 quarters	-0,19	0,51	0,16
8 quarters	-0,19	0,47	0,15
9 quarters	-0,18	0,43	0,15
10 quarters	-0,28	0,36	0,07
11 quarters	-0,39	0,27	-0,01
12 quarters	-0,47	0,18	-0,08

Due to geographic proximity and economic significance of the German economy for the European economies we expect a similar pattern as expected for the US indicators. This effect upon the Norwegian economy would be more immediate compared to that of the US indicators.

The German term spread is defined as:

$$SPREAD\_GER = i_{10years} - i_{1year}$$

The short-term interest rate we use is the one year constant discount rate on government bonds with maturity of one year. This calculation differs from the other spread-variables only because of the non-existence of short-term government securities in the sample.

Norway doesn’t depend only on US business cycles. We also assume European business cycles to be important. Germany is one of the largest economies in Europe and has a central part in the European Union (EU).

As a check on how Norwegian and German business cycles move together we have performed a correlation analysis, in table 12.3. We lag the annual quarterly German GDP growth on the Norwegian GDP to see if the Norwegian real economy lags the German. In the second subsample we get the highest correlation with no lags (0.38). This indicates that we shouldn’t expect the German economy to lead the Norwegian.

As you can see in table 12.4 the two subsamples give very different results when we look at the German term spread as a factor to explain Norwegian GDP growth. The first part of the sample affects the whole sample in such a degree that we don`t get results we can draw any conclusions from. The correlations in the sample from 1997 to 2007 are more in line with what we could expect than in the first subsample, given that the German spread can explain German business cycles. When we don’t use any lags the correlation is negative, although not as notably as in the case of the US term spread. As mentioned earlier we don’t expect the first period in the sample to make any sense. Special occasions in both countries, see discussion in section 2.3, makes it more interesting to study the second period in the case of Norway and Germany.

In the subsample from 1997-2008 we get high correlations from around three quarters (0.40) and highest after seven quarters with (0.51). This result indicates that there can be a relationship between the term spread and future business cycles. Although, it can be discussed whether this is because the development in German business cycles explains change in Norwegian GDP, or if the correlations we get are just caused by the fact that both countries are influenced by the same international trends. The correlations we have estimated in the second subsample indicate that Germany lag US business cycles with more lags than the Norwegian.[28] This result might give support to the theory that we just have followed the same international business cycles.

[28] Appendix 12.1: Correlation between German GDP growth and US GDP growth with lags

Comparing table 5.4 with 12.3 yields the result that the pattern for German GDP and term spread is opposite of what should be expected. However, the last half of the sample is consistent with what can be expected from theory and stronger for the term spread than GDP (see table 12.3). Based on this we choose to exclude the German indicators for the entire sample, but include the German term spread for the latest subsample (Se section 4.1.3) with 4 and 8 lags.

Does US term spread also predict movements in German GDP?

When we studied the correlations of the US term spread on Norwegian annual quarterly GDP growth, the results indicated that the US term spread had explanatory power. Therefore, we find it interesting to see whether there is also a connection with German annual quarterly GDP growth. We would expect qualitatively similar results, because the likely explanation was that the countries follow the same international business cycle. However, we still have to take into consideration that other country specific factors make it difficult to draw any definite conclusions. This is especially important when interpreting the results of the first subsample. While this sample is characterized by some country-specific factors (i.e. German re-unification), it is interesting to consider these factors as explanations of the differences between the two subsamples.

The results in table 12.6 indicate that the US spread can be seen as an explaining factor for German real economic activity. Again, the reader should notice that the correlation is negative when we don't use any lags. In the second subsample it is -0.78, which is a high negative correlation. We find it a bit surprising that we need to lag the US term spread with as much as twelve lags to get the highest correlation (0.41). The correlation even increases if we use more than twelve lags, but we don't find this informative. Other studies have shown that the German economy lag the US economy by around one quarter (Benedictow & Johansen 2005). In appendix 12.1, we report the correlations between annual quarterly GDP growth between the two countries with different lags on US GDP. The results show highest correlations when we use two to six quarters for the second subsample and three to nine quarters when we use the whole sample. Given that the term spread signals four to six quarters ahead, this explain the high number of lags we need to get the highest correlations.

Did the relationship between US GDP and US term spread become weaker?

Earlier in this part, we have looked at whether the US term spread can be used as a leading indicator for Norwegian and German business cycles. This discussion relies on the assumption that we can use the US term spread to predict US business cycles. If the US spread have qualities that make it useful as a leading indicator or early signal on the development of Norwegian business cycles, then it is logical to assume that it must have predicting power over US business cycles. Therefore, we look at the correlations between US GDP and US term spread with different time lags on the spread. The results are given in table 12.6, appendix 12.1..

The indications concerning number of lags and correlations from table 12.6 are as we expected. However, the strength and range of the correlations in the time period 1997-2007 is weaker than expected. Remember, the correlations between US term spread with German and Norwegian GDP showed the expected pattern, larger range and more strength in the correlations. In the US, the correlations are weaker, but they show some expected pattern in the smaller amount of lags. This is especially peculiar since this is the time period we got the highest correlation when we compared the US term spread to Norwegian and German annual quarterly GDP change. This make the earlier discussion and 'evidence' seem less robust. From the existing literature on the subject, we expect stronger and more stable correlations over time. There seems to be some information in the US term spread domestically, but less than expected.

Some studies have claimed that the predictive power of the term spread have decreased in the last decades. According to Estrella (2005a), the term structure seems to decline as the relative policy weight shifts to inflation. The results reported in table 5.4 are consistent with this study. The term spread can be seen as a risk premium for future inflation. We can quantify this risk premium on inflation by using volatility in 10 years government bonds. When future inflation expectations change, so will the prices of long-term government bonds. So, anchoring the inflation rate reduces the predictive power of the term spread, since this policy will reduce the variability in long term inflation expectations, and thus the variability in yield on long term government bonds. This explanation fits together with the volatility perspective on the term spreads leading properties, presented in section 2.3.

The possibility of an international term spread.

One interesting question is whether the US term spread can contain a predictive power over international business cycles although the correlations are poor between domestic GDP and term spread in the US in the second subsample. This can have two explanations:

1. A third factor influence the relationship.
2. The theory of an international term spread.

We do know that the US and European economies are substantially integrated. Economic development in one country tends to have an effect on international economic development. The magnitude of the spillover effect is of course dependent on the size of the economy we study. The US economy is the largest and most influential in world. We would therefore expect that when an economic shock occurs here, it would spread out through the international economic environment. The current subprime crisis originated in the US is an excellent example of such spillover effects. This integration might explain why the US term spread gives such high correlations with Norwegian and German annual quarterly GDP growth. But this does not explain the limited information domestically.

Plosser & Rouwenhorst (1994) introduce an interesting concept; they create something they call a "world interest rate":

> *"The theory says that a "world interest rate" will capture a factor that is common to the growth rate of all countries, and that the national term structures provide additional information about a country's idiosyncratic position relative to the rest of the world."*

They construct the ”world interest rate” from the term structure in US, Germany, UK and Switzerland. According to our results it seems plausible that the US term spread has some of the same qualities as a computed “world interest rate”, or is the main determinant of it (see table 5.3 &12.6)

Whether a domestic or a foreign term spread will have the best predictive power will depend on specific factors for each country. We would also expect these factors to vary over time. The first Norwegian subsample, the time period 1985-1996, seems to contain some country specific factors that make German and US term spread inappropriate as leading indicators for the Norwegian real economy. It then opens the possibility of limited information in the US term spread for the US real economy in the second subsample, while it consists of more information for an international term spread. This suggests some country specific factors in the US, which is not shared by countries affected by an international term spread. Intuitively, such factors could be a special monetary regime or other factors affecting the volatility of the US term spread. However, we couldn’t find any obvious explanations that reconcile with the effect of the US term spread ambiguous effect. This is why we consider it a puzzle.

The Norwegian didn’t, the US did to some degree, what about the German term spread?

In the period we study East- and West-Germany became one country, Germany. Two totally different countries in terms of politics reuniting, one being a former communist state and the other one the most developed countries in the world, definitely qualifies as a special event. It would therefore not be surprising if we see some differences between the two subsamples.

It seems like the German term spread is informative for future German business cycles, even in both subsamples. Although, the number of lags needed to get the highest correlation is a bit surprising. Based on theory we would expect around four to six quarters. All three samples from Germany get the highest correlation after twelve quarters. Before one can draw any conclusions about the German financial markets one should bear in mind that the German term spread is measured as the ten-year Treasury rate less the one-year Treasury rate. According to

Estrella & Trubin (2006) longer maturity differences between short-end and long-end combinations of the term structure generally works better.

Concluding remarks this far

The results from the correlation analysis on the US and German term spread against Norwegian annual quarterly GDP growth are mixed. In the first subsample the correlations are weaker, while in the second subsample the international term spreads seems to exhibit some pattern of correlation with the annual quarterly Norwegian GDP growth. The US term spread leads the annual quarterly GDP growth in Norway with a remarkable high number of lags in the second subsample. The German term spread has a lead time which is shorter and behave more according to expected lead time.

If the German and US term spread are used as leading indicators of the Norwegian real economy, they need to be used with caution. The high correlation we see can be a result of all three countries being dependent on each other and in normal times follow the same international business cycles. The correlation from the first subsample indicates that it can be problematic to use international term spreads, because of country specific events in Norway and Germany (i.e. the unification of East- and West-Germany).

Earlier, we discussed the term “world interest rates” and the additional information they can provide. The results we present from Norway indicate that including an international term spread can make the predictions more reliable. The correlation between the Norwegian term spread and annual quarterly GDP growth is quite high, but the correlations don’t follow a pattern that we would expect given that it had predictive power. It is consistently high across all lags.

There also seems to be a relationship between the US term spread and German business cycles, but it takes three years before we get the highest correlations. This might indicate that German business cycles lag international business cycles in the period we study. Before one can draw any conclusions about fundamental conditions in German financial markets that increase the lead time from the term spread, the following two points should be noted:

- Our measure of the German term spread uses a maturity combination that differs from the standard measure of ten-year less three-month Treasury rates.
- Empirical research has generally established the term spread signaling recessions four to six quarters ahead. The empirical fact does not necessarily translate to high correlations four or six quarters ahead. This is because much of the empirical research use reduced form estimations. And correlation doesn't control for possible third factors which influence the relationship.

We won't do any further research on this, since it is a bit outside the objective of this paper to study why it takes longer time in Germany before both domestic and international term spread predicts changes in GDP.

5.3 The OLS models specified

In section 5.1 we presented a general OLS model. We studied the correlations in section 5.2. In 5.3 we specify the models further so they can be used to estimate our relationship better.

One methodical issue that arises using a distributed lag model is the question of how many lags should be included. Including a lot of lagged values on the independent variables would lead to a substantial loss in degrees of freedom considering the limited sample on several of our variables. This will make the analysis less robust. We choose to include one to two lags of each of the independent variables depending on the correlations and theoretical relationship. Such a small amount of lags are necessary to obtain some degree of confidence in our results, especially in the two smaller subsamples.

Another issue specific to the OLS model we estimate is the fact that some of our variables are on the form of annual quarterly growth. We therefore choose to include lags with at least three quarters interval to avoid serial correlation between the independent variables. Regarding the other independent variables we must accept some serial correlation and colinearity in order to study the relationship with annual GDP growth[29].

When it comes to GDP growth, we also observe annual quarterly growth. Since the dependent variable is on this form, the model contains a known form of autocorrelation in the error term. The real economic activity defined as annual quarterly growth produce observations that at least needs to be corrected for three lags of autocorrelation. This does not produce biased coefficient estimates, but the standard errors are affected by this. We use the Newey West corrected standard errors described in section 5.4.

The theoretical starting point of our analysis is the following equation:

$$Norwegian\_realeconomic\_activity = Domestic\_Spread + Oilsector + \\ Foreign\_Spread + Error \tag{3}$$

[29] In example, to assume the interest rate in one period to be independent of previous periods would be flawed, due to the interest rate setting rules of today's monetary policy regimes. Also it would be flawed to assume uncorrelated interest rates between countries.

Our primary interest according to our hypothesis is the information content of the term spread upon the Norwegian real economy. This assumes that the term spread actually contains expectations of future real economic activity. Under this assumption, past observations of the term spread influence the present real economy activity, and present observations contain information about the future real economic development. Due to the specific nature of the Norwegian business cycles we also control for the influence of the oil sector and foreign expectations of real economic activity through foreign term spreads. Implicit in this approach is the expectation that the term spread reflect all the internal economic relations that create real economic activity. Thus, a considerable amount of attention should be addressed to whether the error term is systematic in some way. If the assumptions for the error term hold, it would imply stronger evidence in favor of the term spread as containing information about business cycle expectations and thus the real economic activity in real time.

Using the variables discussed in the section above with the specified lags, our population model can be formulated in the following way:

$$\begin{aligned} GDP\_NO_t &= \beta_0 + \beta_1 SPREAD\_NO_{t-2} + \beta_2 SPREAD\_NO_{t-6} + \beta_3 OILINV_t + \\ &\beta_4 OILINV_{t-8} + \beta_5 SPREAD\_US_{t-8} + \beta_6 SPREAD\_US_{t-12} + u_t \end{aligned} \quad (4)$$

We estimate the same model for the entire sample, and the first subsample. For the second subsample the German spread is included:

$$\begin{aligned} GDP\_NO_t &= \beta_0 + \beta_1 SPREAD\_NO_{t-2} + \beta_2 SPREAD\_NO_{t-6} + \beta_3 OILINV_t + \\ &\beta_4 OILINV_{t-8} + \beta_5 SPREAD\_US_{t-8} + \beta_6 SPREAD\_US_{t-12} + \beta_7 SPREAD\_GER_{t-4} + \\ &\beta_8 SPREAD\_GER_{t-8} + u_t \end{aligned} \quad (5)$$

In addition, we vary which independent variables that are included, to estimate the best possible model to predict real economic activity.

5.4 The results

In this section we present the results of the standard OLS regression analysis. As in the correlation analysis we first estimated the whole sample and then divided the sample into two subsamples ranging from 1985 to 1996 and 1997 to 2008. We include two different lags of each variable, since we don't want the variables to be close in time. Using lags that overlap the same annual quarterly GDP growth can cause co-linearity between the independent variables. This is why we include lags of the independent variables which are at least four quarters apart. But first, we elaborate and scrutinize the OLS assumptions.

Regarding the OLS assumptions

First, we are studying data that for the most part are annual quarterly growth rates. These are comparable to returns data, and thus expected to be stationary (unlike the level of economic time series). This is likely to produce stable OLS estimates over time. The results of the tests for stationarity, are reported in appendix 12.3. The Augmented Dickey Fuller tests show support against the null-hypothesis, that the annual quarterly growth of the Norwegian GDP is non-stationary. This may come across as a surprise, considering Norges Bank's staff memo (Husebo & Wilhelmsen 2005) studies which argue that the Norwegian GDP consist of a stochastic trend. This implies that simple differentiation is not sufficient to obtain stationarity, because shocks have permanent effect. However, we study annual quarterly growth which is seasonally adjusted, and the ADF-tests are therefore reliable. Further, this gives reason to believe that the cumulative and marginal growth rates also are stationary. The oil-investments also reject the null-hypothesis. The spread terms are more problematic. While the US term spread reject the null, the Norwegian don't. The German reject the null only assuming a drift term in the estimation. We reason that it is plausible to perform the usual OLS regressions without differencing the spread terms. The basis for this decision is that the spread terms are already terms that are differenced and reflect the change in interest rates from three months to ten years. In addition, the individual interest rates comprising the various spreads are also returns like GDP growth rate. Like the GDP, on which we don't study the level but the growth rate, we don't study the price but the return on various government bills and bonds.

Second, we know that the data on the annual quarterly growth rates consist of overlapping observations. These produce a known pattern of serial correlation in the error term. Any given observation of a annual quarterly growth rate, is obtained using three quarterly observations that are also used to obtain the previous growth rate. This is likely to produce some bias in the estimated standard errors, whereas the coefficient estimates remain unaffected.

To be convinced that the hypothesis tests are correct, we produce standard errors using the approach of Newey and West[30] (1987). For the known overlapping observations, we correct for k-1 lags of serial correlation. In addition, we control for serial correlation in the non-overlapping data. That is we adjust the standard errors for moving average terms that are larger than k-1. The method follow these four steps:

1. Run the usual OLS regression with non-corrected standard errors.
2. Produce Bartlett's MA(q) diagram, and observe q where autocorrelation approach zero.
3. Perform the Breusch-Godfrey test for serial-correlation up til lag q choosen in point 2.
4. Run the OLS regression with Newey West corrected standard errors either corrected for k-1 lags if no serial correlation exist for lags>k-1. If serial correlation exist for lags>k-1, correct for the last lag that rejects the null-hypothesis of no serial correlation in the Breusch-Godfrey test.

The estimated standard errors are robust both to serial correlation (or autocorrelation) and heteroskedasticity following this approach. Thus, further tests on these issues should not be necessary. The results of this analysis of amount of lags that needs to be corrected are presented in appendix 12.2.

[30] The procedure includes determining standard errors that take height for the known serial correlation. This is easily implemented in stata by running a *newey*-regression, where we define a number of lags that should be corrected for serial correlation and heteroskedasticity. The method produce standard errors that are equal to the ones produced with standard ols if one define zero lags of serial correlation.

Finally, the question of whether the errors are normally distributed is addressed. This is important to our results because we divide the sample into two subsamples that are quite small. The underlying assumptions that justify the t- and F-tests rely on valid normal errors. To examine the validity of the normal assumption, we perform the skewness and kurtosis test described in D'Agostino et.al (1990). The objective of this test is to determine whether the distribution of the underlying population is normally distributed or not. Two parameters describing the skewness (displacement) and kurtosis ('peakness') of the distribution are weighed to form a joint test observator and a corresponding p-value. The null hypothesis is normality, and the alternative hypothesis is non-normality. Because of the way the null hypothesis is formulated, the decision to reject or don't reject the null is associated with some degree of judgment. In example, a relevant judgment would be what level of significance that is acceptable to reject normality. This is a crucial judgment when testing small samples, because you want to be able to draw conclusions about the sample through the tests which assume normality in small samples. In addition, due to the procedure of statistical inference you can never accept the alternative hypothesis, only reject the null.

The results of the skewness and kurtosis tests are reported in appendix 12.4. We base our rejection rule at 5% significance level. Here is a summary of the results of the tests:

- Of the Norwegian term spreads, the most frequently used term spread is the ten-year less three month spread. This term spread fail to reject the null in the two subsamples, but rejects the null when tested in the entire sample. When tested for the entire sample, the Norwegian term spread come significant at the kurtosis dimension.
- The oil variables reject the null, except in the first subsample. It seems to be a combination of both the kurtosis and skewness dimension that rejects the composite null hypothesis.
- Of the foreign term spreads, the US term spread don't reject the null in the entire subsample, but reject the null in both subsamples. In both subsamples, it is the kurtosis that causes the rejection. The German term spread only reject the null in the first subsample, also on the kurtosis dimension.

- Of the GDP variables, the US GDP rejects the null in the first subsample and the entire sample. The German GDP also rejects the null in the entire subsample. Other than that, the GDP variables fail to reject the null hypothesis. For both the German and US GDP, it seems to be a combination of kurtosis and skewness that is problematic.

When assessing the importance of these results it is necessary to consider that financial price variables generally are considered to be lognormal, when unedited. When edited to returns data through differencing or taking the logarithm, they are considered normal. Of the term spread's that reject normality, kurtosis seems to be the problem. This means that our differencing between the various maturities of the term spreads makes them normal on the skewness dimension. The kurtosis makes the distribution more peaked than the normal distribution. The GDP and oil variables are more problematic, because it is a combination of both dimensions of normality that rejects the null. Based on the correlations in the previous section, the connection between foreign term spreads and Norwegian GDP seems to be stronger compared to the relation between foreign and Norwegian GDP. The normality issue also makes it more interesting to include foreign term spreads, and not foreign GDP terms in our models. The Norwegian GDP doesn't reject the null hypothesis of normality and contributes to more reliable t- and f-tests. The oil investments should be interpreted with care in the models we estimate.

It would be flawed to assume the normality condition for OLS to be valid without some reservation in our analysis, especially in the smaller subsamples. Nevertheless, we choose to carry out the analysis of the models assuming normality. This can be justified to some degree, because the models are additive and the effects on the real economic activity are financial variables measured by growth. Additive models with approximately normal variables satisfy the normality required in the error terms for proper inference (Wooldridge 2006). Normality in the errors is much more crucial in models containing multiplicative terms. Having this in mind, we interpret the results with some reservation, especially the oil investments and the models estimated in the subsample.

5.4.1 The OLS regressions

The OLS regression is presented in table 5.5 – 5.7. Based on earlier discussion we only include the German term spread in the subsample from 1997 – 2008. The adjusted r-squared tells us how well the variables explain changes in the annual quarterly GDP growth. The significance levels of the estimated coefficients tells us how likely it is that we reject the null hypothesis when the null hypothesis is actually true. The smaller the P-value the more significant is the result. The interpretation of the estimated spread-coefficients is: For a given level of the term spread, this corresponds to an annual quarterly GDP change measured in percent. A positive coefficient implies an increase in annual quarterly Norwegian GDP growth, while a negative variable implies a decrease annual quarterly Norwegian GDP growth. This is the isolated effect of the term spread coefficients. The interpretation of the annual quarterly growth in oil investments are similar, but show the change in GDP growth for a given change in oil investments.

Significant coefficients on the term spreads are support of rejecting the null hypothesis about no information in the term spread. In table 5.5, which presents estimates of the period from 1985 to 2007, it is evident that the Norwegian term spread has the largest effect on Norwegian annual quarterly GDP change. With two lags the Norwegian term spread is significant different from zero at 1% level, while it is significant at 5% level when it is lagged with six quarters. For an inversion at -2% level, the Norwegian term spread lagged six quarters predict an annual quarterly change in GDP of -1.1028% at present time *t*. Lagged two quarters the same level of the spread predicts a change of -1.0068% at time *t*. The small difference between the two predictions in this model, underline the small range of the correlations in the previous section. This means that the information in the term spread is not very accurate; it provides relatively small amount of additional information as we vary the lags. Growth in oil investments have quite small coefficients, but are still significant different from zero on a 1% level when we use eight lags on the variable. The US term spread has quite low estimated coefficients, and both lags are not significant different from zero at 10% level. The coefficient with twelve lags is even going in the opposite direction of what we expected. This is a bit surprising considering the positive correlation the variable had with annual quarterly

Norwegian GDP change. The independent variables explain approximately 35% of the variation in annual quarterly GDP growth, and are jointly significant different from zero at 1% level.

TABLE 5.5: OLS REGRESSION 1985-2007

85 OBSERVATIONS

F (6, 78) = 28.24

PROB > F = 0.0000

ADJUSTED - R^2 = 0.3494

Variables	Coefficient	St.dev	T
Constant	0.0199	0.0032	6.23 (0.000)***
Norwegian term spread Lag 2	0.5034	0.0716	7.03 (0.000)***
Norwegian term spread Lag 6	0.5514	0.2568	2.15 (0.035)**
Growth oil investments	0.0078	0.0050	1.56 (0.122)
Growth oil investments Lag 8	0.0224	0.0038	5.95 (0.000)***
US term spread Lag 8	0.1348	0.2718	0.50 (0.621)
US term spread Lag 12	-0.1778	0.2886	-0.62 (0.540)

T-statistics; *, ** and *** denote significance at the 10%, 5% and 1% level respectively. The p-value of the coefficients is reported in parenthesis behind t-value.

In table 5.6, the period from 1985 to 1996, the results are different. In this period, the US term spread used with eight lags is the only statistical significant coefficient. The coefficient is also the highest. The Norwegian term spread used with six lags have quite high coefficients, but isn't statistically different from zero at 10% significance level. In this period, the US term spread lagged twelve quarters give a high negative coefficient, which is significant different from zero at 10% level. This large anomaly explains why this variable has a negative coefficient in the whole sample from 1985 - 2007. Again, growth in oil investments contains most information after eight quarters, but it isn't statistically different from zero at none of our significance levels. The adjusted r-squared is 0.2904, which is the lowest of the periods we test. It still indicates that the variables have some explanatory power and the F – value is high. This means that at least one of the included variables is different from zero.

TABLE 5.6: OLS REGRESSION 1985-1996

41 OBSERVATIONS

F (6, 34) = 10.62

PROB > F = 0.0000

ADJUSTED - R^2 = 0.2904

Variables	Coefficient	St.dev	T
Constant	0.0074	0.0079	0.94 (0.356)
Norwegian term spread Lag 2	0.1825	0.2443	0.75 (0.460)
Norwegian term spread Lag 6	0.5437	0.3567	1.52 (0.137)
Growth oil investments	0.0006	0.0074	0.08 (0.933)
Growth oil investments Lag 8	0.0191	0.0119	1.60 (0.118)
US term spread Lag 8	0.9331	0.2134	4.37 (0.000)***
US term spread Lag 12	-0.6234	0.3091	-2.02 (0.052)*

T-statistics; *, ** and *** denote significance at the 10%, 5% and 1% level respectively. The p-value of the coefficients is reported in parenthesis behind t-value.

In table 5.7, the subsample from 1997 to 2008, we include the German term spread. The Norwegian term spread is statistically significant different from zero at 5% level. However, with six quarters lag it is not significant. Actually it goes in the opposite direction. The fact that the direction is negative in this period is quite surprising, especially considering the high positive correlations we found in section 5.1 between annual quarterly Norwegian GDP growth and six lags of the term spread. The estimates seem to be affected by co-linearity among the term spreads that are included.

TABLE 5.7: OLS REGRESSION 1997-2007

44 OBSERVATIONS

F (5, 35) = 10.11

PROB > F = 0.0000

ADJUSTED - R^2 = 0.5991

Variables	Coefficient	St.dev	T
Constant	0.0188	0.0132	1.42 (0.165)
Norwegian term spread Lag 2	0.7130	0.3200	2.23 (0.032)**
Norwegian term spread Lag 6	-0.0724	0.2891	-0.25 (0.804)
Growth oil investments	0.0088	0.0076	1.15 (0.256)
Growth oil investments Lag 8	0.0148	0.0068	2.16 (0.037)**
US term spread Lag 8	-0.1489	0.3476	-0.43 (0.671)
US term spread Lag 12	0.6647	0.2219	3.00 (0.005)***
German term spread Lag 4	-0.7592	0.4948	-1.53 (0.134)
German term spread Lag 8	0.7216	0.4254	1.70 (0.099)*

T-statistics; *, ** and *** denote significance at the 10%, 5% and 1% level respectively. The p-value of the coefficients is reported in parenthesis behind t-value.

The directions of the US term spread is now opposite of what they we're in the sample from 1985 to 1996. In Table 5.7, the US term spread is different from zero at a 1% significance level when we use twelve lags, the coefficient is also high. On the other hand, the coefficient is negative when we use eight lags, moving in the opposite direction. We also included the German term spread lagged with four and eight quarters. The German term spread also gives mixed signals. When the German term spread is lagged by eight quarters the coefficients is positive and quite high, although not significant different from zero. However, when we use four lags on the German spread, it moves in the opposite direction, indicating that an increase in the term spread leads to decrease in the annual quarterly GDP growth four quarters later. As for growth in oil investments, we find again that the oil investments lagged by eight quarters give more information than no lags. The coefficient lagged by eight quarters is small, but significantly different from zero at a 5% level

Remarks

The results we have presented so far in this section are ambiguous. We have found a relationship between the Norwegian term spread and the annual quarterly growth in Norwegian GDP, but this is in-accurate when we interpret the Norwegian term spread isolated. In addition, some of the estimates behave different than we expect from the theory. For instance in the period from 1997 – 2008, the Norwegian term spread lagged with six quarters has a negative coefficient. This implies that a positive Norwegian term spread will decrease the annual quarterly GDP growth four quarters later, and a negative term spread will increase the quarterly GDP growth four quarters later. This ambiguous result is also present for some of the models which include international term spread estimates, which we believe is mainly due to co-linearity.

The results suggest that it is problematic to interpret the estimates isolated in such a model. Instead, the compound effect of all the independent variables may behave more consistent with theory. This is a bit strange since multiple OLS estimate the partial effect of each of the independent variables (Wooldridge 2006). Our results indicate that foreign term spreads supplement the domestic, with additional information regarding the real economic activity especially in the first subsample.

The adjusted r-squared explain around one third in the first subsample and the whole sample from 1985 to 2007. For the second subsample, from 1997 to 2007 it explains as much as 60%. This is very high. The same regression without the German term spread estimates an adjusted r-squared which is about 56%. So, it is evident that the second subsample behaves more like we expected given theory and explains more of the Norwegian annual quarterly GDP growth. The F-tests are significant at 1% level for all samples.

The growth in the oil investments variable seems generally to work better with eight lags than zero lags. This suggest a slow responsiveness of GDP on demand from the oil sector. For the whole sample, oil investments lagged with eight quarters are significant different from zero at 1% level. However, the coefficients are quite small and but the effect on annual quarterly GDP growth can be large when considering that they are measured in millions of Norwegian Kroner.

Since some of the results were a bit surprising, i.e. that the Norwegian term spread lagged with six quarters is negative in the sample from 1997 – 2008, we suspect that there might be some interaction between our variables making the results hard to interpret. Therefore, we found it interesting to do the same OLS regressions excluding the foreign term spreads and oil investments. Then we will also find out how much explanatory power the international influence provide additional to the Norwegian term spread.

5.4.2 OLS regressions excluding international term spreads and oil investments

In table 5.8 the results of the OLS regression in which we only included the Norwegian term spread lagged with two and six quarters as explanatory variables are presented. The constant coefficient is small, but significant different from zero at 1% level. The estimated coefficients on the different term spreads are almost equal as when we included more variables in section 5.4.1. Two quarters lag on the term spread is still significantly different from zero on a 1% level while six quarters lags are significantly different from zero on a 5% level. The adjusted r-squared has decreased from 0.3494 to 0.3144. This means that including two different lags of oil investments and the US term spread don't increase the explanation power of the model by very much, when we examine the whole sample. This indicates that the international influences didn't give much additional information. It also implies that the Norwegian term spread predicts movements in annual quarterly GDP almost as good alone as when we included oil investments and US term spread. The F - value is 18.33 and implies that at least one of the variables is different from zero.

Table 5.8: OLS regression 1985-2007

85 observations

F (2, 82) = 18.33

Prob > F = 0.0000

Adjusted - R^2 = 0.3144

Variables	Coefficient	St.dev	T
Constant	0.0199	0.0037	5.46 (0.000)**
Norwegian term spread Lag 2	0.5054	0.0865	5.84 (0.000)**
Norwegian term spread Lag 6	0.5372	0.2409	2.23 (0.028)*

T-statistics; *, ** and *** denote significance at the 10%, 5% and 1% level respectively. The p-value of the coefficients is reported in parenthesis behind t-value.

We also divided the whole sample into two subsamples in this section. First, we examine the period from 1985 to 1996 in table 5.9. The different lags of the Norwegian term spread still have a positive direction which is what we would expect given theory. However, we find that neither are significant different from zero. The constant coefficient is significant different from zero at 5% level.

It is important to notice that the adjusted r-squared has decreased considerably from 29% to 5% in table 5.9. This implies that when we exclude the US term spread and oil investments as independent right hand side variable the result weaken considerably. This period was evidently affected by international impulses and the Norwegian term spread alone doesn't give a very good indication of future Norwegian GDP growth. As a result of this the F – value is low (2.47) and we cannot conclude that at least one of the variables in the regression is different from zero. This is consistent with our discussion earlier, where we have argued that the period from 1985 to 1996 needs to be separated from the rest of the sample because of the way monetary policy were conducted in some parts of this period and other country specific factors.

TABLE 5.9: OLS REGRESSION 1985 - 1996

41 OBSERVATIONS

F (2, 38) = 2.47

PROB > F = 0.0981

ADJUSTED - R^2 = 0.0528

Variables	Coefficient	St.dev	T
Constant	0.0143	0.0056	2.53 (0.016)**
Norwegian term spread Lag 2	0.2847	0.2730	1.04 (0.304)
Norwegian term spread Lag 6	0.3233	0.5010	0.65 (0.523)

T-statistics; *, ** and *** denote significance at the 10%, 5% and 1% level respectively. The p-value of the coefficients is reported in parenthesis behind t-value.

TABLE 5.10: OLS REGRESSION 1997 - 2008

44 OBSERVATIONS

F (2, 41) = 16.46

PROB > F = 0.0000

ADJUSTED - R^2 = 0.4111

Variables	Coefficient	St.dev	T
Constant	0.0256	0.0043	5.91(0.000)***
Norwegian term spread Lag 2	0.5902	0.1066	5.54 (0.000)***
Norwegian term spread Lag 6	0.4297	0.1749	2.46 (0.018)**

T-statistics; *, ** and *** denote significance at the 10%, 5% and 1% level respectively. The p-value of the coefficients is reported in parenthesis behind t-value.

Table 5.10, presents the results of the same regression in the subsample from 1997 to 2008. The estimates implies that the Norwegian term spread explain much of the movement in annual quarterly Norwegian GDP change. The estimated constant coefficient is significant. The coefficient for the term spread lagged six quarters is positive, which give the opposite effect on GDP compared to the estimates including more independent variables. Actually, it is now significant different from zero at 5% level. The term spread lagged with two quarters is also more robust and is significant different from zero on a 1% level. The adjusted r-squared has decreased from about 60%, but it still explains as much as 41% of the movements in annual quarterly GDP growth which is impressive. And then the F value is of course high.

Concluding remarks

In this section we have seen that the explanatory power of the Norwegian term structure varies depending on which time period we study. Not surprisingly we find that the term spread is not appropriate as a leading indicator unless we include the US term spread to reflect the international influence on the sample from 1985 to 1996. The international influence is quite prominent in both subsamples and the whole period. In the second subsample our variables explain as much as 60% of the movements in the Norwegian annual quarterly GDP growth when the international influences and oil investments are controlled for. This is impressive.

5.4.3 A better OLS model

TABLE 5.11: OLS REGRESSION 1985-2007

85 OBSERVATIONS

F (3, 81) = 12.12

PROB > F = 0.0000

ADJUSTED - R^2 = 0.2915

Variables	Coefficient	St.dev	T
Constant	0.0169	0.0064	2.66(0.009)***
Norwegian term spread Lag 6	0.7855	0.2584	3.04(0.003)***
Growth oil investments Lag 8	0.0213	0.0040	5.27(0.000)***
US term spread Lag 8	0.2008	0.1366	1.47(0.146)

T-statistics; *, ** and *** denote significance at the 10%, 5% and 1% level respectively. The p-value of the coefficients is reported in parenthesis behind t-value.

In the last section we observed that the interpretation of the different estimated coefficients became qualitatively different as we included or excluded more variables. This is because the variables are co-linear. The idea behind this section is to include the best elements of the previous section and exclude some of the variables to avoid co-linearity. Based on common theory regarding lead times in the term structure and the results in the previous section we pick out the variables that hopefully yield the best results. In table 5.11 – 5.13 we only include the Norwegian term spread lagged six quarters, growth in oil investments lagged eight quarters and the US term spread lagged eight quarters.

The results in table 5.11 – 5.13 are similar to the results we obtain in table 5.5 - 5.7. However, excluding some of the variables we remove some of the results that weren't compatible with what we expected. In example, the Norwegian term spread coefficient lagged six quarters and the US term spread coefficient lagged eight quarters is no longer negative, but positive in the subsample from 1997-2007. This indicates that the negative coefficients in table 5.7 were due to co-linearity and not a caused by a negative connection between the variables and the annual quarterly GDP growth. The coefficient of the Norwegian term spread lagged six quarters increased in table 5.11 compared table 5.5. In table 5.5 a 1% increase in the term spread would lead to a 0.55% increase in the annual quarterly GDP growth. In table 5.11 a similar increase in the Norwegian term spread would lead to a 0.79% increase in the annual quarterly GDP growth. The only result that seems to be considerably weaker when we drop the mentioned variables, is the adjusted r-squared in the second subsample. However, all in all the results gives better information when we drop some of the variables, since the magnitude and direction of the coefficients seems to be more reliable.

TABLE 5.12: OLS REGRESSION 1985-1996

41 OBSERVATIONS

$F(3, 37) = 5.78$

PROB > F = 0.0024

ADJUSTED - $R^2 = 0.2616$

Variables	Coefficient	St.dev	T
Constant	-0.0024	0.0074	-0.33(0.744)
Norwegian term spread Lag 6	0.4970	0.3250	1.53(0.135)
Growth oil investments Lag 8	0.0207	0.0091	2.27(0.029)**
US term spread Lag 8	0.7866	0.2212	3.56(0.001)***

T-statistics; *, ** and *** denote significance at the 10%, 5% and 1% level respectively. The p-value of the coefficients is reported in parenthesis behind t-value.

The estimated coefficients in the first subsample are interesting. Both the oil investments and the US term spread come out significant at 5% and 1% level respectively. Furthermore, the r-squared is higher compared to when the model includes the Norwegian term spread alone. Also, the Norwegian term spread estimate come out in-significant together with the constant term.

Table 5.13: OLS Regression 1997-2007

44 OBSERVATIONS

F (3, 40) = 6.78

PROB > F = 0.0008

ADJUSTED - R^2 = 0.2808

Variables	Coefficient	St.dev	T
Constant	0.0251	0.0059	4.25(0.000)***
Norwegian term spread Lag 6	0.5811	0.2513	2.31(0.026)**
Growth oil investments Lag 8	0.0177	0.0061	2.91(0.006)***
US term spread Lag 8	0.2121	0.3264	0.65(0.520)

T-statistics; *, ** and *** denote significance at the 10%, 5% and 1% level respectively. The p-value of the coefficients is reported in parenthesis behind t-value.

Concluding remarks

The results of the model including the best properties of the previous OLS models are in general better. This is because we include fewer lagged term spreads, and the problem caused by co-linearity is solved. This results in more significant estimates, and coefficients that behave more in accordance to theoretical influence over real economic activity. Although the US term spread doesn't come out significant different from zero on the levels we test in all samples, it still show the "theoretical right" sign.

6. A structural model – the Estrella & Hardouvelis OLS model

In addition to the OLS models estimated in part 5, we estimate a second model using OLS, which use the econometric techniques of Estrella & Hardouvelis (1991), considered the standard approach. This approach has been replicated by several other studies, including Bernard & Gerlach (1996) which find evidence for both domestic and foreign term spreads in their analysis. This approach should be fairly robust to analyzing different variables and countries.

The model is quite similar to the one described in the previous section. We can redefine the measure of real economic activity in the following two ways to describe the cumulative and marginal change of the GDP over a given horizon respectively:

$$GDP\_NO_{t,t+k} = (400/k)\left[\ln(GDP\_NO_{t+k} / GDP\_NO_t)\right] \quad (6)$$

$$GDP\_NO_{t+k-j,t+k} = (400/j)\left[\ln(GDP\_NO_{t+k-j} / GDP\_NO_{t+k})\right] \quad (7)$$

Here, k denotes the forecasting horizon and j adjusts the forecasting horizon from cumulative to marginal growth. Thus, the difference between this representation of GDP and the one used in the previous OLS model is that instead of using annual growth it uses annualized growth. Where $k=4$ the two representations become similar, but not equal, for the marginal change variable.

Using the representations in (4) and (5) we estimate the following equations:

$GDP\_NO_{t,t+k} = \beta_0 + \beta_1 SPREAD\_NO_t + u_t$,where $k = 1,2,..8,12,16,20.$ (8)

$GDP\_NO_{t+k-j,t+k} = \beta_0 + \beta_1 SPREAD\_NO_t + u_t$,where $k = 1,2,..8,12,16,20.$

and $j=1$ for $k = 1,2,..8.$, and $j=4$ for $k = 12,16,20.$ (9)

The term spread is defined as in section 5.2.2. Again, we use the Newey West corrected standard errors, corrected by the same procedure as described in section 5.4.

6.1 The results

In this section we present the basic OLS regression results, based on the models of Estrella & Hardouvelis (1991). We do regressions for both cumulative (table 6.1) and marginal change (table 6.2) in GDP. Consistent with theory, a certain level of the term spread implies an increase (decrease) in future growth in real output. In example, if the term spread between ten-year Treasury bonds and three-month Treasury bills are 100 basis points, then the cumulative change of the fourth row in table 6.1 predicts that GDP is expected to grow 0.78% (0.02% + (0.76)(1%)= 0.78%) during next four quarters. Furthermore, the models include a constant term. A positive constant indicates that a negative term spread does not necessarily forecast a negative future GDP development.

TABLE 6.1: OLS REGRESSION CUMULATIVE CHANGE

Forecasting horizon, k quarters	N	β_0	t	β_1	t	$\overline{R}^2$	SSE
1 quarter	89	0.0215(0.0040)	5.34(0.000)***	0.810 (0.2637)	3.08(0.003)***	0.0478	0.1552
2 quarters	88	0.0210(0.0038)	5.48(0.000)***	0.8244(0.2476)	3.33(0.001)***	0.1570	0.0499
3 quarters	87	0.0210(0.0036)	5.83(0.000)***	0.7561(0.2346)	3.22(0.002)***	0.1884	0.0341
4 quarters	86	0.0208(0.0035)	5.97(0.000)***	0.7578(0.2247)	3.37(0.001)***	0.2350	0.0261
5 quarters	85	0.0203(0.0037)	5.52(0.000)***	0.7691(0.2355)	3.27(0.002)***	0.2855	0.0208
6 quarters	84	0.0201(0.0036)	5.53(0.000)***	0.7668(0.2114)	3.63(0.000)***	0.3159	0.0178
7 quarters	83	0.0201(0.0037)	5.48(0.000)***	0.7625(0.1933)	3.95(0.000)***	0.3426	0.0156
8 quarters	82	0.0201(0.0038)	5.29(0.000)***	0.7610(0.2089)	3.64(0.000)***	0.3522	0.0147
12 quarters	78	-0.0170(0.0036)	-4.67(0.000)***	-0.575(0.1554)	-3.70(0.000)***	0.3206	0.0089
16 quarters	74	0.0213(0.0041)	5.24(0.000)***	0.5304(0.1756)	3.02(0.003)***	0.2371	0.0093
20 quarters	70	0.0220(0.0039)	5.66(0.000)***	0.3138(0.1686)	1.86(0.067)*	0.1035	0.0077

T-statistics; *, ** and *** denote significance at the 10%, 5% and 1% level respectively. The estimated betas of the regression of the cumulative change in GDP on the term spread are reported together with the corrected standard errors in parenthesis. The p-value of the coefficients is reported in parenthesis behind t-value.

TABLE 6.2: OLS REGRESSION MARGINAL CHANGE

Forecasting horizon, k quarters	N	β_0	t	β_1	t	$\overline{R}^2$	SSE
1 quarter	89	0.0215(0.0040)	5.34(0.000)***	0.8108(0.2637)	3.08(0.003)***	0.0478	0.1551
2 quarters	88	0.0210(0.0046)	5.59(0.000)***	0.8430(0.2897)	2.91(0.005)***	0.0529	0.1533
3 quarters	87	0.0221(0.0050)	4.45(0.000)***	0.6228(0.3387)	1.84(0.069)*	0.0235	0.1579
4 quarters	86	0.0215(0.0048)	4.50(0.000)***	0.7877(0.3149)	2.50(0.014)**	0.0445	0.1544
5 quarters	85	0.0196(0.0052)	3.75(0.000)***	0.8794(0.3564)	2.47(0.016)**	0.0665	0.1347
6 quarters	84	0.0206(0.0049)	4.25(0.000)***	0.8475(0.2761)	3.07(0.003)***	0.0625	0.1312
7 quarters	83	0.0209(0.0052)	4.06(0.000)***	0.8270(0.2991)	2.76(0.007)***	0.0584	0.1317
8 quarters	82	0.0211(0.0052)	4.09(0.000)***	0.8395(0.2938)	2.86(0.005)***	0.0598	0.1313
12 quarters	78	0.0215(0.0048)	4.45(0.000)***	0.6872(0.1804)	3.81(0.000)***	0.1823	0.0261
16 quarters	74	0.0256(0.0043)	6.00(0.000)***	0.2487(0.2124)	1.17(0.245)	0.0148	0.0230
20 quarters	70	0.0281(0.0042)	6.68(0.000)***	-0.3581(0.1723)	-2.08(0.041)*	0.0539	0.0183

T-statistics; *, ** and *** denote significance at the 10%, 5% and 1% level respectively. The estimated betas of the regression of the cumulative change in GDP on the term spread are reported together with the corrected standard errors in parenthesis. The p-value of the coefficients is reported in parenthesis behind t-value.

In table 6.1, all the estimated coefficients, both β_0 and β_1, are positive except the twelve quarters estimate on cumulative change where both the estimated coefficients are negative. This result is quite odd and we don’t want to put too much emphasize on it, since we don’t know what’s causing it. We consider this to be an anomaly or a signal that the term spread is unreliable and/or in-accurate. There is no obvious theoretical reasons why the twelve quarters estimate should be negative, while both preceding and subsequent estimates are positive.

Because all β_0 are quite small, only a small inversion of the term structure will predict negative GDP growth in our sample. When we compare our results to the results of Estrella & Hardouvelis (1991), we find that they estimate higher coefficients; especially the constant terms are high compared to our results. The r-squared which estimates how much of the change in GDP growth is explained by the term spread are qualitatively the same, both in magnitude and the pattern they follow over various k. Besides different time period and country, Estrella and Hardouvelis study real changes in GNP while we study real changes in GDP. We don't expect this to affect the qualitative interpretation of the results. Isachsen et al. (1998) estimate the same model using Norwegian data, and our results are similar to the estimate in that study. Their sample is shorter, but show the same tendency to estimate smaller constant terms.

If you carefully study the results you might find it odd that the model roughly predicts the same GDP growth whether you test for one quarter or eight quarters ahead. After all, the GDP growth is cumulative. The same pattern is also present in the Estrella and Hardouvelis article. However, if you look at the r-squared you see that the explanatory power are different meaning that after i.e. eight quarters the models explain much more of the change in GDP than after one quarter.

When we compare the two tables we find that the cumulative changes in real output are more predictable than marginal changes. This is also consistent with the Estrella and Hardouvelis`s findings. The predictive power of the term spread over the cumulative change seems to be present for around sixteen quarters or four years. However, the predictive power of the term spread over the marginal change doesn't indicate any specific time horizon that outperforms others. The r-squared is quite high after twelve quarters, but this is probably a coincident. Estrella and Hardouvelis find that the predictive power of the term spread over consecutive marginal changes in real output lasts for about six or seven quarters. Within these quarters they observe relatively low r-squared, but with a clear pattern. Our r-squared are also small, but not consistent with the pattern that they observe.

The results from table 6.2 can be used to calculate how low the term spread has to be in order to predict a recession in each of the particular following quarters. If we use a standard definition of a recession as two consecutive quarters of negative GDP growth, the required level of the term spread that predict a recession can be calculated. This is done by dividing the negative value of the constant term over the coefficient of the slope. In example, a term spread of minus 0.0355 percent will predict a negative growth in GDP from quarter t+2 to t+3 (for

K=3).[31] The same inversion is big enough to predict a negative growth in GDP from quarter t+3 to t+4 (for K=4), and thus predicts a recession. This means that the term structure almost doesn't have to be inverted to signal a recession. The result is not convincing and is probably due to our small sample. However, as we mentioned above it is not surprising because of the small constant terms we obtain from the regression.

Although we might not be able to use this models a predictors of recessions, both the models are definitely evidence that certain levels of the term spread goes together with an increase (or decrease) in GDP. In table 6.1 all the coefficients, except the slope coefficient after twenty quarters, are significant different from zero 1% level. This supports the rejection of the null hypothesis of this study. However, the results after twelve quarters are the opposite of what we would expect and imply that a decreased term spread leads to an increase in GDP growth.

While the statistical significance of the spread coefficients provides evidence regarding the direction of the future change in GDP, the R-squared provides information on how accurate the sample predicts movements in GDP. In table 6.1 the term spread explain around one third of the change in GDP from six to twelve quarters. According to Estrella and Hardouvelis this is impressive.

[31] A spread of -0.0265=(-0.0215)/0.8108 is required to predict negative growth in GDP from quarter t to t+1, -0.0249 from t+1 to t+2, -0.0355 from t+2 to t+3 and -0.0273 from t+3 to t+4.

7. The reduced form model – the probit

7.1 A general model

Whereas the objective of the time series models in the previous part was to describe the variability in y_{it} from variations in the independent variables over time, the objective of the reduced form estimation is to test the predictive power of the independent variables where y_{it} take on only two values. A binary response model allow the y_{it} to take on the value of zero or one, and estimates the response probabilities of the independent variable(s). The probit model is a specific version of such a model. The theoretical rationale behind such a model would be that the term structure could be a better predictor of dramatic changes in real economic activity, than smaller changes like the ones that use continuous measures of real economic activity.

Mathematically, binary response models take the form:

$$P(y=1|\mathbf{x}) = G(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_K x_K) = G(\beta_0 + \boldsymbol{\beta}\mathbf{x}) \tag{10}$$

, where G is a function which takes on values between zero and one, and $\boldsymbol{\beta}\mathbf{x}$ is the vector of independent variables and the corresponding coefficient estimates. In the probit model, G is defined as the standard normal cumulative distribution function, which ensures response probabilities between zero and one for all values of the independent variables:

$$G(z) = \Phi(z) = \int_{-\infty}^{z} \phi(v)dv \tag{11}$$

Here, $\phi(z)$ is the standard normal density $\phi(z) = (2\pi)^{-\frac{1}{2}} \exp\left(\frac{-z^2}{2}\right)$. Adjusted to our empirical relationship the probit model can be expressed the following way:

$$P(y_{t,t+q}) = 1|\mathbf{x}) = G(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_K x_K) = G(\beta_0 + \boldsymbol{\beta}\mathbf{x}) \tag{12}$$

, where the vector of the independent variables at time t forecasts the state of y, k quarters ahead. This presentation is in line with Wooldridge (2006).

The probit model can be estimated using maximum likelihood estimation (MLE). Because of nonlinearity, OLS cannot be applied here and must be estimated using the density of y_i given $\mathbf{x}_i$:

$$f(y|\mathbf{x}_i;\boldsymbol{\beta}) = [G(\mathbf{x}_i\boldsymbol{\beta})]^y[1 - G(\mathbf{x}_i\boldsymbol{\beta})]^{1-y}, y = 0,1.$$

The log-likelihood function for an observation i is a function of the parameter vector β and the data $\mathbf{x}_i y_i$. The log-likelihood function can be obtained by taking the logarithm of (12):

$$\ell_i(\boldsymbol{\beta}) = y_i \log[G(\mathbf{x}_i\boldsymbol{\beta})] + (1 - y)\log[1 - G(\mathbf{x}_i\boldsymbol{\beta})] \tag{13}$$

For a sample size n, the log-likelihood function is:

$$L(\boldsymbol{\beta}) = \sum_{i=1}^{n} \ell_i(\boldsymbol{\beta}). \tag{14}$$

The MLE of equation (14) maximizes this log-likelihood.

The probit models are useful as reduced form evidence only. The lack of a single theory to explain the relation between the term spread and the business cycles may explain why the reduced form models are so popular in empirical studies on this subject. Reduced form evidence is less causal and cannot be attributed to the underlying theoretical foundations. The strength of the reduced models compared to structural models, are that the performance seems to depend less on the choice of sample periods compared to continuous models. Several studies confirm that the reduced form models perform about as well as structured models measured in accuracy and robustness over time (Estrella 2005b).

7.2 The variables

Numerous studies have been conducted on the term structure using probit models with different independent variables. From the original but still popular formulation using only the domestic term spread as in Estrella & Hardouvelis (1991), to the more sophisticated models which in example use real interest rate and the central bank's folio rate. Wright (2007) provides an interesting study using different spread related measures (such as interest rate risk premium) to overcome some of the simplifying assumptions of the earlier models. Due to limitations in the available data and risks of wrong estimation, our study uses more traditional measures on the different term spreads[32].

Regarding the independent variables we considered a few econometric issues that are associated with using them in a binary estimation. First, we study the level of the term spread. According to Estrella & Trubin (2006), the level of the term spread proves the most accurate in predicting recessions in probit-models. The definition of a recession often implies some kind of change in real GDP. This suggests studying the change in the term spread rather than the level. But studying the level of the term spread is already including a forward looking change in the interest rate. Second, we consider the same independent variables from the continuous models. The definitions of the independent variables are equal to the definitions that were used in the structural models.

The right-hand-side variable must be on the form of a dummy variable, which only take on the values zero or one. Thus, when we want to study real economic activity measured by a quarterly recession indicator, the definition of a recession is imperative for the outcome of the study. There exists a few different approaches to do this and different studies have chosen different definitions. We considered the following alternatives for dating recessions in our study:

[32] In example, we wanted to use the Norwegian real interest rate to capture the variations in monetary policy over time. This proved difficult, because of a change in the computation of the appropriate inflation measure (KPI) over time. Thus, to estimate actual inflation in a period we would rely on several assumptions which is associated with increased risk of a flawed comparison over time.

1. The production-gap method described in Norges Bank's Staff memo (Husebo & Wilhelmsen 2005). In, this approach the definition of a business cycle is crucial. Either you choose to study classical or growth cycles, and date recessions accordingly.
2. Some rule of thumb. This definition is often less precise, but often the recessions concur with officially dated recessions if the rule is reasonable.

Both methods are associated with some degree of judgment. Choosing alternative one, you have to decide upon what trend the GDP growth consist of, and how to estimate this. Further, several of the approaches include some judgment in setting parameters of the models that estimate the trend (i.e. HP-filtering and λ).Choosing alternative two, would include choices on what growth measure to use and how many quarters in a row with negative growth it takes to classify a recession.

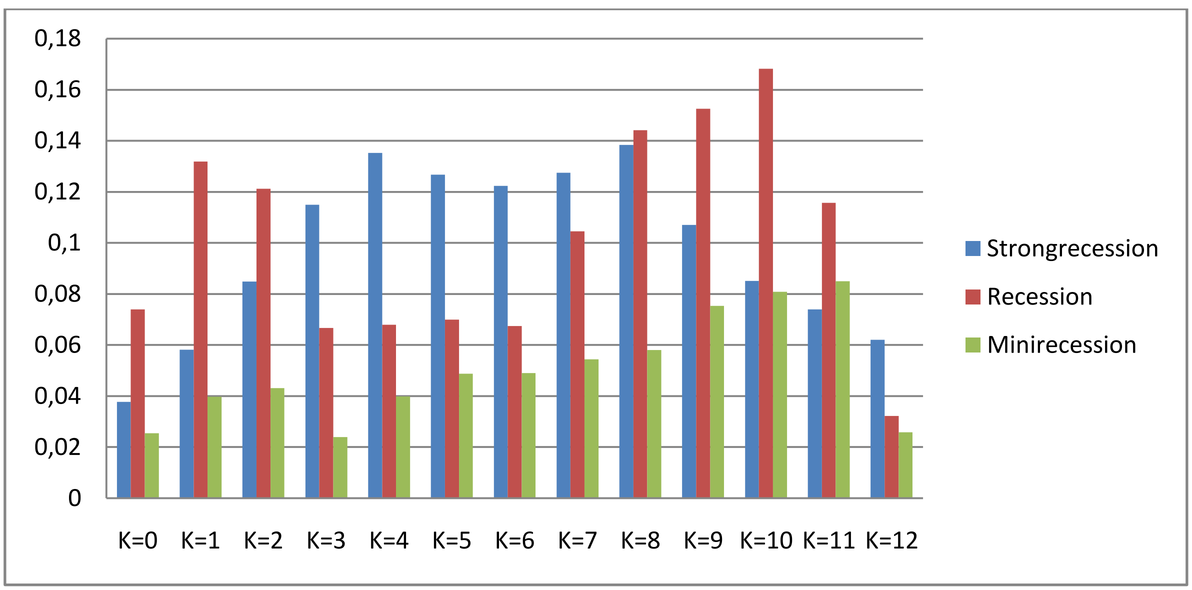
While both are associated with some degree of judgment, approach two provide reasonable insight when supplemented with information from the recessions estimated with approach one by the Central Bank of Norway (Husebo & Wilhelmsen 2005). It's a simplifying, but nevertheless a useful approach. To make sure we use the most reasonable rule of thumb we define the following rules and regress the estimated recessions it produce on the ten-year minus three-month term spread of Norway in order to decide which one provides the most reliable results:

1. Strongrecession: The dummy equals one if the annual quarterly growth in real GDP is negative for two consecutive quarters and zero otherwise.
2. Recession: The dummy equals one if the quarterly growth in real GDP is negative for two consecutive quarters and zero otherwise.
3. Minirecession: The dummy equals one if the growth in real GDP is negative for one quarter and zero otherwise.

The results of these regressions are reported in appendix 12.5. It turns out that the strong recession dummy yields only two recession observations in our sample. And the minirecession is to weak a signal for the spread to actually capture it. Having this in mind we choose the dummy using two consecutive quarters of negative quarterly growth in our study. Using this rule of thumb fulfill our purpose when we supplement with the Central Bank of Norway's study. We get enough recession signals to perform a probit regression, and the signals are reliable enough to draw some information from our estimates when supplemented with other information.

In figure 7.1 we show how well each of the recession definitions are explained by the Norwegian term spread. On the X-axis we have plotted different lags of the spread. I.e. K=4 refers to how well the Norwegian term spread four quarters ago explain the different recession definitions today. The y-axis measures the pseudo r-squared. As we can see the 'mini-recession' come out worst measured by pseudo r-squared, while the 'strong-recession' and 'recession' definitions varies depending on how many quarters ahead you study.

FIGURE 7.1: PSEUDO R SQUARED FOR DIFFERENT MEASURES OF RECESSION



Source: Authors own calculations.

With the recession indicator determined we adjust it in the following two ways to fit our division between backward and forward looking models respectively (see next section):

$Recession_t =$ 1 if quarterly GDP growth is negative in both quarter t and $t-1$, or t and $t+1$.

0 otherwise.

$Recession_{t,t+k} =$ 1 if $Recession_t$ equals one at least one quarter from in quarters t to $t+k$.

0 otherwise.

7.3 The models specified

Before we go into the details on the models we estimate, we first define to types of models. We separate between backward-and forward-looking models. The backward-looking models lag the independent variables ($t-k$) against present dependent variable (t); for the rest of this study this will be called recession in-k-quarters models. The forward looking variables use the present value of the independent variables (t) against future values of the dependent variable ($t, t+k$); for the rest of this study this will be called recession within-k-quarters models.

First, we want to determine what maturity combination of the term spread that works best regarding the Norwegian real economy. To examine this we consider two models; the first use the various maturity combinations lagged eight quarters ($t-8$) and the second use the spread at time t to estimate the probability of a recession during the next six quarters ($t, t+6$):

$$P(Recession_t = 1) = G\left(\beta_0 + \beta_1 SPREAD\_NO_{t-8}^{Xyears - Ymonths}\right) \tag{15}$$

$$P(Recession_{t,t+6} = 1) = G\left(\beta_0 + \beta_1 SPREAD\_NO_{t}^{Xyears - Ymonths}\right) \tag{16}$$

Second, we want to determine at what horizon the term spread predicts best. In these studies we estimate the same models with varying independent variables. The independent variables of our interest are $SPREAD\_NO$, $SPREAD\_US$, $SPREAD\_GER$ and $OILINV$ .We estimate both the recession-in-k-quarters and recession-within-k-quarters models for different combinations of the independent variables:

$$P(Recession_t = 1) = G\left(\beta_0 + \beta_1 SPREAD\_NO_{t-k}^{10years - 3months}\right) \tag{17}$$

$$P(Recession_{t,t+k} = 1) = G\left(\beta_0 + \beta_1 SPREAD\_NO_{t}^{10years - 3months}\right) \tag{18}$$

$$P(Recession_t = 1) = G\begin{pmatrix}\beta_0 + \beta_1 SPREAD\_NO_{t-k}^{10years - 3months} + \\ \beta_2 SPREAD\_US_{t-k}^{10years - 3months}\end{pmatrix} \tag{19}$$

$$P(Recession_{t,t+k}=1)=G\begin{pmatrix}\beta_0+\beta_1 SPREAD\_NO_t^{10years-3months}+\\ \beta_2 SPREAD\_US_t^{10years-3months}\end{pmatrix} \quad (20)$$

$$P(Recession_t=1)=G\begin{pmatrix}\beta_0+\beta_1 SPREAD\_NO_{t-k}^{10years-3months}+\\ \beta_2 SPREAD\_GER_{t-k}^{10years-1year}\end{pmatrix} \quad (21)$$

$$P(Recession_{t,t+k}=1)=G\begin{pmatrix}\beta_0+\beta_1 SPREAD\_NO_t^{10years-3months}+\\ \beta_2 SPREAD\_GER_t^{10years-1year}\end{pmatrix} \quad (22)$$

$$P(Recession_t=1)=G\begin{pmatrix}\beta_0+\beta_1 SPREAD\_NO_{t-k}^{10years-3months}+\\ \beta_2 SPREAD\_US_{t-k}^{10years-3months}+\\ \beta_3 SPREAD\_GER_{t-k}^{10years-1year}\end{pmatrix} \quad (23)$$

$$P(Recession_{t,t+k}=1)=G\begin{pmatrix}\beta_0+\beta_1 SPREAD\_NO_t^{10years-3months}+\\ \beta_2 SPREAD\_US_t^{10years-3months}+\\ \beta_3 SPREAD\_GER_t^{10years-1year}\end{pmatrix} \quad (24)$$

$$P(Recession_t=1)=G\begin{pmatrix}\beta_0+\beta_1 SPREAD\_NO_{t-k}^{10years-3months}+\\ \beta_2 OILINV_{t-k}\end{pmatrix} \quad (25)$$

$$P(Recession_{t,t+k}=1)=G\begin{pmatrix}\beta_0+\beta_1 SPREAD\_NO_t^{10years-3months}+\\ \beta_2 OILINV_t\end{pmatrix} \quad (26)$$

7.4 The results

In this section we present and interpret results of the probit model explained in the previous section. When we know the term spread, the probit model makes it possible to predict the probability that we will enter a recession in or within k quarters.

The probit model uses the standard normal distribution to convert the term spread into a probability of a recession in or within k quarters ahead. We tested for both the probability of a recession in one specific quarter k and also the probability of a recession within k quarters, meaning from today to quarter k. Details of this calculation are given in the textbox below (Estrella & Trubin 2006).

Textbox 7.1: The probit models

The probit model gives a probability of a recession in the time period we specify. **First** we predict a recession in period t, with information k quarters ago:

$P(recession_t) = G(\beta_0 + \beta_1\ SPREAD\_NO_{t-k})$,

where $SPREAD\_NO_{t-k}$ is the difference between Norwegian ten-year Treasury bonds and three-month Treasury bills in quarter t-k, β_0 and β_1 are constants, G is the cumulative normal distribution function

$$\phi(z) = (2\pi)^{-\frac{1}{2}} \exp\left(\frac{-z^2}{2}\right)$$

and $P(recession_t)$ *is* the probability of a recession occurring in quarter t from the information available in the term spread in quarter t-k.

Second we predict a recession within quarter k, with this equation:

$P(recession_{t,t+k}) = G(\beta_0 + \beta_1\ SPREAD\_NO_t)$,

where t, t+k denotes from period t until period t+k. The rest of the notation is the same as above.

In both models the probability of a recession is easy to compute with a standard spread sheet. The probability is computed using the formula:

NORMSDIST(β_0+ β_1*A1),

where A1 indicates the cell that contains the specific percentage value of the term spread. If you want to find the term spread that goes together with a specific recession probability then you use this formula:

(NORMSINV(B1)+ β_0)/ β_1,

where B1 indicates the cell that contains the recession probability.

The interpretation of the estimated coefficients is straightforward: A positive (negative) coefficient is interpreted as an increase (decrease) in the probability of a recession for a given level in the term spread (k quarters ago for the in-k-quarters models and in quarter t for the within-k-quarters model). The pseudo r-squared is a measure of the 'goodness-of-fit' for the regression, and vary from zero to one. Just like the r-squared in the OLS models, the pseudo r-squared in the probit models corresponds to the null hypothesis that all the coefficients except the constant term are zero.

7.4.1 Testing different maturity combinations of the term spread

According to yield curve FAQ you get better results when you forecast real economic activity by taking the difference between two Treasury yields whose maturities are far apart. Most empirical research have used the ten-year rate in the long end of the term structure, which is the longest maturity available in most countries, computed on a consistent basis over a long sample period.[33] At the short end of the term structure it isn't a clear consensus of what maturity that is most appropriate. The overnight rate is probably a too short maturity as the monetary authorities directly control it. Market analysts often use the difference between ten-year and two-year Treasury rates to compute the term spread, while some academic researchers have preferred the difference between the ten-year Treasury rate and the federal funds rate (Estrella & Trubin 2006). However, Estrella and Mishkin (1998) suggest that the three-month Treasury rate combined with the ten-year Treasury rate gives a reasonable combination of accuracy and robustness over long time periods.

[33] Yield curve FAQ: http://www.newyorkfed.org/research/capital_markets/ycfaq.html#Q6

TABLE 7.1: PROBIT ON RECESSION WITH DIFFERENT NORWEGIAN TERM SPREADS LAGGED EIGHT QUARTERS

Term spread	Spread percent (β_1)	Z	Constant (β_0)	Z	Pseudo – R^2	Log likelihood
10Y – 3m	-0.54 (0.25)	-2.21 (0.027)**	-1.38 (0.24)	-5.76 (0.000)***	0.1442	-22.43
10Y – 6m	-0.62 (0.29)	-2.14 (0.033)**	-1.37 (0.24)	-5.66 (0.000)***	0.1470	-22.36
10Y – 9m	-0.65 (0.31)	-2.09 (0.037)**	-1.35 (0.24)	-5.68 (0.000)***	0.1434	-22.46
10Y – 12m	-0.63 (0.30)	-2.08 (0.038)**	-1.33 (0.23)	-5.83 (0.000)***	0.1334	-22.72
5Y – 3m	-0.56 (0.27)	-2.12 (0.034)**	-1.37 (0.22)	-6.13 (0.000)***	0.1118	-23.28
5Y – 6m	-0.66 (0.32)	-2.07 (0.038)**	-1.36 (0.22)	-6.06 (0.000)***	0.1137	-23.23
5Y – 9m	-0.70 (0.35)	-2.01 (0.045)**	-1.35 (0.22)	-6.09 (0.000)***	0.1086	-23.37
5Y – 12m	-0.67 (0.34)	-1.95 (0.051)*	-1.32 (0.21)	-6.21 (0.000)***	0.0961	-23.70
3Y – 3m	-0.87 (0.37)	-2.36 (0.018)**	-1.51 (0.26)	-5.75 (0.000)***	0.1643	-17.40
3Y – 6m	-1.11 (0.48)	-2.32 (0.021)**	-1.51 (0.27)	-5.64 (0.000)***	0.1709	-17.27
3Y – 9m	-1.19 (0.54)	-2.19 (0.028)**	-1.48 (0.26)	-5.68 (0.000)***	0.1556	-17.58
3Y – 12m	-1.01 (0.50)	-2.03 (0.043)**	-1.43 (0.24)	-5.95 (0.000)***	0.1188	-18.35

Z-statistics; *, ** and *** denote significance at the 10%, 5% and 1% level respectively. The estimated coefficients are reported together with the standard errors in parenthesis. The p-value of the coefficients is reported in parenthesis behind z-value.

In table 7.1 we present the results of the probit model, which estimate the probability of a recession using different maturity combinations of the Norwegian term spread. We have estimated the probit model in order to see what maturity that has the best prediction of two consecutive quarters of negative GDP growth ($Recession_t$). In the long end of the term structure we vary between three, five and ten years, and in the short end we vary between three, six, nine and twelve months. For the models that include three-year interest rate, the sample period is from 1987 quarter two to 2007 quarter four. For the remaining models the sample period is from 1985 quarter two to 2007 quarter four.

The results for the various maturity combinations are of course qualitatively similar. There is a high correlation between interest rates and therefore the results shouldn't vary too much depending on what maturities we use as long as they are far apart. However, the different maturities might apply different in terms of predicting the future outlook of the economy. In example, the ten-year minus the two-year Treasury rate term spread is known to be inverted earlier than the ten-year minus three-month. On the other hand, the ten-year minus the three-month inversion tend to be larger (in absolute value).

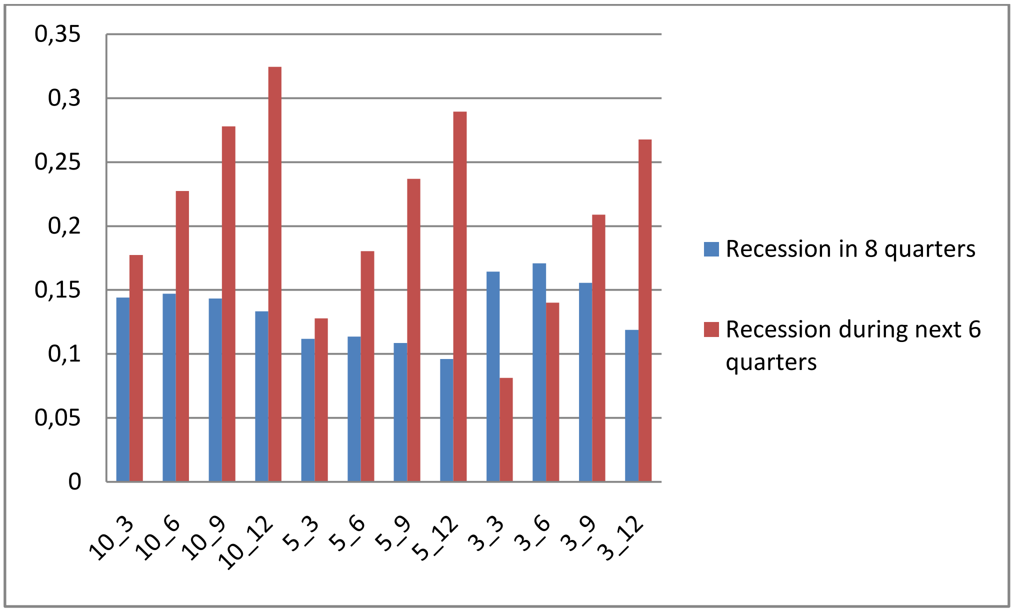
Our regression results show that the three-year Treasury rate has a higher pseudo r-squared than five- and ten-year Treasury rates. This is a bit surprising since most empirical research show that the ten-year Treasury rate usually is more appropriate in the long end of the term structure. Nevertheless, the ten-year Treasury rate has a higher pseudo r-squared than the five-year Treasury rate. In figure 7.1 you can see this graphically. The graphs also show pseudo r-squared when we estimate how well the model explain recession within six quarters. In that case the result is different; within six quarters the Norwegian term spread explain more of the changes in $Recession_{t,t+k}$ when we use ten-year minus three-month compared to three-year minus three-month Treasury rates.

All the estimated coefficients in table 7.1, except one, are significant at a 5% level. We find that the β_0 terms are quite similar, ranging from -1.33 to -1.51, all significant at a 1% level. On the other hand, the estimated constants on the term spread, β_1 , varies more. These estimates indicate that the longer maturity that applies to the long end of the term structure, the lower the probability of recession will be for a given term spread. In example, a 1% inversion using the ten-year minus three-months Treasury rate will give a probability of recession that is 20% (NORMSDIST(-1,38+-0,54*-1))[34], while the probability of a recession using three-year minus nine-months Treasury rate is 39% (NORMSDIST(-1,48+-1,19*-1)). We haven't found any literature that study this issue, but we suspect that it might be a result of the ten-year Treasury rate being more stable than i.e. the three-year Treasury rate. Since the longer maturities

[34] Calculation done in Excel

contain less noise, it is natural that it will not predict as many recessions as the shorter maturities which are more volatile. Thus, it reduces the risk of producing false recession signals.

FIGURE 7.1: PSEUDO R SQUARED FOR DIFFERENT MEASURES OF THE NORWEGIAN TERM SPREAD



Source: Authors own calculations.

Deciding on how to compute the 'right' term spread one should consider some criteria. First, the data must be available. Second, the Treasury-bill or –bond's liquidity. If the trade volume is small, the Treasury might be mispriced due to some market imperfections. Third, the government might interfere in the market for interest rates and the Treasury might be issued at politically fixed prices, which does not match how the market would have priced the Treasuries.

As written earlier in this thesis we have found it most appropriate to define the term spread as the difference between the ten-year and the three-month Treasury rate. We base this decision on what most other empirical research has concluded to give the best results and what our own testing has indicated. The ten-year Treasury rate is probably less volatile than shorter maturities and a recession signal will therefore be more robust compared to if we use a shorter maturity at the long end of the term structure. As showed in figure 7.1 it also explains more of the movement in $Recession_{t,t+k}$ when we test for a recession during the next six quarters. After all, an analysis of the recession probability over the next six quarters is more interesting than an analysis of one specific quarter. An analysis over the next six quarters is less volatile and contains more information. A prediction of one specific quarter is surrounded by high uncertainty and not as useful when we make predictions.

7.4.2 Predictive power of the domestic term spread in and within k quarters

In this section we present the results of a probit regression on the domestic term spread. We test how well different lags of only the domestic (Norwegian) term spread predict variations in the recession dummies. We test for recession in both one specific quarter k and within k quarters. In table 7.2, the Norwegian term spread β_1 is significant at 10% level in each quarter up until twelve quarters ahead. The constant β_0 is significant at a 1% level in all quarters we present in the table. In regards of the pseudo r-squared, the term spread explains more of the movements in the recession dummy around eight and ten quarters ahead, compared to any of the other horizons. Twelve quarters seems to be a too long horizon and it is not significant. As we also can see when we test within k quarters, the Pseudo-R^2 doesn't increase much by adding the 12th quarter.

We test for a recession within k quarters and find that all the estimated spread coefficients are significant at a 1% level. The pseudo r-squared are of course increasing as we add another quarter to the regression. The constant β_0 is significant at a 1% level until within eight quarters where it isn't significant at any level we test. The results in this test indicates that the Norwegian term spread do have predictive power over real economic development. The predictive power seems to last from around two until ten quarters ahead, and the term spread seems to behave in a pattern that is plausible given theory regarding the term structure as a leading indicator. We also suspect that the results would be even more convincing if we had excluded the period in the late eighties and early nineties when Norwegian monetary policy was pro-cyclical.

We see in the table that all the coefficients as expected are negative in the recession in-k-quarters estimates, meaning that a decrease in the term spread will increase the probability of a recession. The information in the domestic term structure seems to have decreased when the horizon is twelve quarters. The spread constant β_1 is lower than on the other quarters and it is the only quarter that isn't significant different from zero. Of the other horizons, quarters two, eight and ten is significant different from zero at 5% level. But as explained later quarter eight and ten might be a coincident. All the constants β_0 are stable and negative varying from -1,29 to -1,41.

TABLE 7.2: PSEUDO R SQUARED AND Z-STATISTICS FOR PROBIT MODELS USING DOMESTIC TERM SPREAD, RECESSION IN AND WITHIN QUARTER K

	Number of quarters (k) ahead						
	0	2	4	6	8	10	12
Recession in quarter k							
Pseudo – R^2	0.0739	0.1212	0.0680	0.0675	0.1442	0.1682	0.0322
Spread β_1	-0.35(0.19)	-0.47 (0.22)	-0.33 (0.19)	-0.33 (0.19)	-0.54 (0.25)	-0.61 (0.27)	-0.22 (0.18)
Z – value	-1.81 (0.071)*	-2.17 (0.030)**	-1.73 (0.083)*	-1.72 (0.086)*	-2.21 (0.027)**	-2.29 (0.022)**	-1.17 (0.243)
Constant β_0	-1.32(0.20)	-1.35 (0.22)	-1.30 (0.20)	-1.29 (0.20)	-1.38 (0.24)	-1.41 (0.25)	-1.33 (0.20)
Z – value	-6.68 (0.000)***	-6.29 (0.000)***	-6.53 (0.000)***	-6.45 (0.000)***	-5.76 (0.000)***	-5.58 (0.000)***	-6.50 (0.000)***
Log likelihood	-25.00	-23.56	-24.81	-24.63	-22.43	-21.63	-22.79
Recession within quarter k							
Pseudo – R^2		0.1339	0.1519	0.1775	0.2116	0.2798	0.2842
Spread β_1		-0.50 (0.19)	-0.53 (0.16)	-0.56 (0.15)	-0.61 (0.14)	-0.74 (0.16)	-0.75 (0.16)
Z – value		-2.63 (0.009)***	-3.30 (0.001)***	-3.83 (0.000)***	-4.24 (0.000)***	-4.60 (0.000)***	-4.59 (0.000)***
Constant β_0		-1.10 (0.19)	-0.70 (0.16)	-0.40 (0.16)	-0.20 (0.16)	-0.02 (0.16)	0.13 (0.16)
Z – value		-5.84 (0.000)***	-4.25 (0.000)***	-2.56 (0.010)***	-1.27 (0.204)	-0.11 (0.912)	0.78 (0.433)
Log likelihood		-30.48	-39.78	-43.70	-43.63	-40.07	-38.70

Z-statistics; *, ** and *** denote significance at the 10%, 5% and 1% level respectively. The estimated coefficients are reported together with the standard errors in parenthesis. The p-value of the coefficients is reported in parenthesis behind z-value.

Probability of recession graphs for Norway

In this section we have used the probit model from the section above to calculate and graph the probability of a recession in Norway. These predicted probabilities correspond to the fitted values of standard OLS models. We have graphed both the probability of a recession in one specific quarter and the probability within the next k quarters. We present and discuss only some of the graphs since the qualitative interpretation is basically the same. The rest of the graphs can be found in appendix 12.6.

Recession within six quarters

Figure 7.3 show the probability of a recession during the next six quarter in Norway predicted by the Norwegian term spread. The shaded areas represent the recessions in our sample. The graph is based on the estimates in table 7.2 and the probabilities can be calculated by the same procedure as described in textbox 7.1. In example, the probability of a recession during the next six quarters in the fourth quarter 1998 will be 81%.[35] In the recession within-k-quarters models, the probability of a recession increase as we add another quarter. This goes without saying since it is obvious that the probability of a recession during the next quarters will increase if you add more quarters to your forecast horizon. However, the probabilities increases and decreases more or less in the same quarters. If you take a random point in the graph, this probability is based on the Norwegian term spread at time t.

When we decided to include the graph that shows the probability of a recession during the next six quarters in the text, it wasn't just a random pick. Theory concerning the term structure indicates that the term spread usually predicts a recession around four to six quarters ahead. If you also consider monetary policy actions, a prediction on this horizon will also be very useful as they often base their policy on a short- and intermediate horizon.

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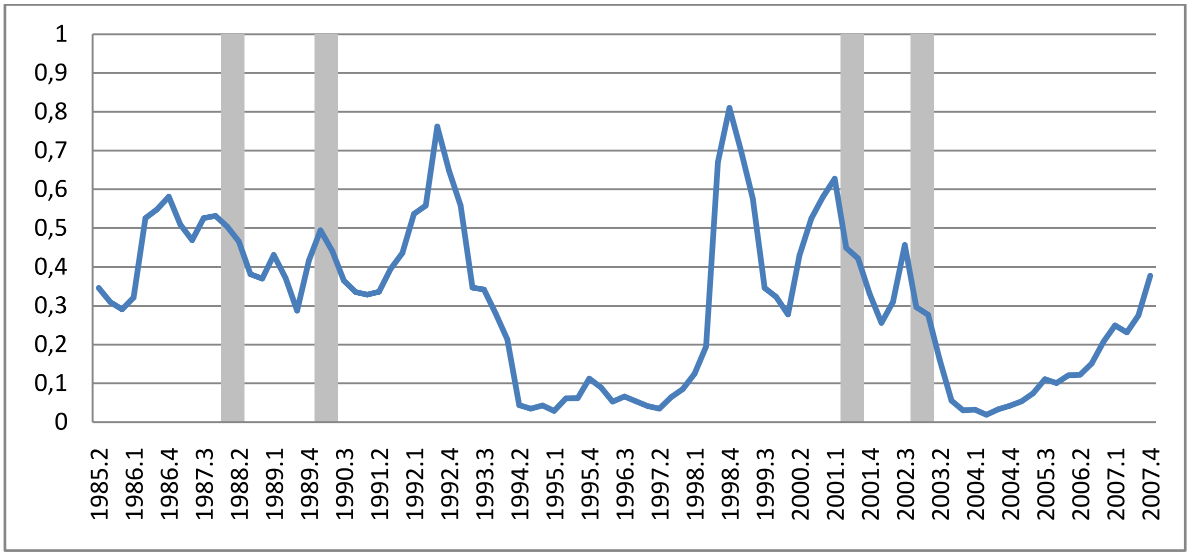
[35] NORMSDIST(-0,4-0,56*-2,27))=0.81. The probability is calculated in a spread sheet. The term spread, (-2,27) is from the data material and the constant coefficients in table 7.2.

FIGURE 7.3: PROBABILITY OF RECESSION WITHIN SIX QUARTERS, NORWEGIAN TERM SPREAD ALONE.



Source: Authors own calculations.

In figure 7.3, the Norwegian term spread seems to some degree predicts recessions, but the two highest probabilities aren't followed by a recession by our definition. However, if we analyze these two quarters we can find some evidence that makes it plausible for the model to predict high recession probabilities. The first 'false' recession signal was in the third quarter in 1992 and the probability of a recession was as high as 76%. Below six possible explanations for this high recession probability are listed:

1. As mentioned above, there is uncertainty in the way we define a recession. It is possible that our recession definition, two consecutive quarters of negative real GDP growth, don't capture a recession. The peak in the third quarter 1992 has a probability of 76% of being followed by a recession during the next six quarters. In the preceding years Norway had experienced a banking crisis. The GDP growth was minus two percentages compared to trend growth and had been below trend growth for about three or four

years.[36] Given this information it is plausible to state that we already were in a recession that is not included in our measure of a recession.

2. A second possible explanation is related to the human forecasting model.[37] The human forecasting model states that the market participants have a tendency to be too pessimistic when times are bad and too optimistic when times are good. At the time, the real economy had been slow for a few years. The GDP growth was below trend growth and unemployment was high and increasing.[35] So the high probability might be a result of the slow growth in the real economy and the dismal view of the economic future. The term structure is an indicator of the markets expectation of future economic growth (Isachsen et al. 1998). If the market expectations are irrational and to some part driven by mass-psychology then the term structure might give misleading information.
3. A third possible explanation is the monetary policy that where conducted in this period.[38] Because of a fixed exchange rate the Norwegian central bank could influence business cycles only limited through monetary policy. This period had high real interest rates and a pro-cyclical monetary policy enforced the bad times on the Norwegian economy. Since monetary policy to a large degree have direct control over the short end of the term structure,[39] we have in large parts of this thesis operated with two subsamples. The results have clearly indicated that the Norwegian term spread alone has less or none prediction power in the first subsample from 1985 to 1996.[40]
4. The fourth possible explanation has a connection to the monetary policy argument. As we can see from the start of the sample in 1985 until the peak in the third quarter 1992, there is constantly a quite high probability of a recession during the next six quarters. The probabilities are ranging from around 30% to 60%. Ideally the probabilities should be volatile and vary from very low probabilities to high probabilities depending on the

[36]Tor Anders Husebo & Bjorn-Roger Wilhelmsen, Norges Bank staff memo 2/2005: "Norwegian Business Cycles 1982-2003: http://www.norgesbank.no/upload/import/publikasjoner/staff_memo/memo-2005-02.pdf. The estimate of GDP is based on figure 3, in this staff memo.

[37] See figure in appendix 12.7 from lecture in Konjunkturanalyse by Harald Magnus Andreassen.

[38] See the theory section where monetary policy and how it affected Norwegian business cycles are discussed in detail.

[39] And have an indirect effect on the long end of the term structure.

[40] See table 5.9 in section 5.2. Here, the Norwegian term spread alone only explain 5% of the changes in annual quarterly GDP growth. If we include the US term spread and oil investments we explain 29%, see table 5.6.

term spread. When the probabilities are around 50% of a recession during the next six quarters as in figure 7.3, the term spread isn't very useful to predict the real economy and cannot be used as a leading indicator. The high probabilities reflect that the term structure was inverted or nearly inverted in a large part of the sample period from 1986 until 1994. After this period the probabilities seems more volatile and as the results showed in part 5, the Norwegian term spread also contains more information.

5. There is a possibility of the model being less accurate when it predicts probabilities of recession within instead of in one specific quarter. The within-k-quarters models will always predict higher probabilities as another quarter is added to the prediction horizon. Taking this into consideration, the in-k-quarter models could be more reliable given that the optimal prediction horizon is found.
6. International currency turmoil can explain the high probability of a recession. The European Exchange Rate Mechanism (ERM) gave currencies a central exchange rate against the ECU[41]. National currencies had an upper and lower limit on either side of this central rate within which they could fluctuate. The fall of 1992 the ERM had collapsed partly due to currency speculation. Especially George Soros is well-known for 'forcing' Bank of England to devaluate the Pound Sterling. By short-selling the Pound Sterling by such a large amount and consequently betting that the Pound Sterling would be devalued. The Bank of England tried to keep the Pound Sterling within the boundaries set by the ERM, but was forced to devalue because of the speculation. George Soros claimed to have a total position worth ten billion USD against the Pound Sterling.[42] At the same time both Italy and Spain were also forced to devalue their currencies. And Sweden abolished their fixed exchange rate, while Norway abolished the fixed exchange rate against ECU. This explanation seems plausible since Norway also dropped the fixed exchange rate policy against the ECU in quarter four 1992, the same quarter as we get the high 'false' probability of a recession.

[41] ECU (European Currency Unit) was a basket of currencies of the European Community member states, later replaced by the Euro.
[42] Wikipedia, George Soros: *http://en.wikipedia.org/wiki/Soros*

After the high recession probability in 1992 some years with low probabilities follow, before it peaks again in the fourth quarter in 1998. In the third quarter in 1998 the probability of a recession during the next six quarters is 67% and in the fourth quarter it was as high as 81%. This is a false signal according to our definition of a recession. Below, there are listed several incidents that together led to an inverted term structure and signaled such a high probabilities:

- In the summer 1997, the crisis that has been known as the Asia-crisis started in Thailand. The crisis hit especially Thailand, Malaysia, Indonesia and South-Korea hard. It spread out through East-Asia and then international business cycles. To sum it up briefly, there was a financial crisis (stock markets crashed, after being brought artificially high by foreign capital), exchange rate crisis (exchange rates where overrated) and a real economic crisis (GDP growth fell for the countries that where involved).[43] Because of financial contagion the Asia-crisis led to a short, but international recession. As we will discuss below it, was the main reason that Norwegian three months rates almost doubled from under four to almost eight percent within a few months.
- In summer 1998, a financial crisis hit Russia. Exacerbated by the Asia-crisis Russia defaulted on their government debt spreading throughout international financial markets. The Asia-crisis and the Russian debt default together contributed to collapse of the hedge fund Long Term Capital Management (LTCM).
- In the first quarter in 1998 the three-month Treasury bill that we use to compute the term structure was on average 3,96% while in the last quarter of 1998 it was 7,70%. It almost doubled in under a year! As discussed under section 2.3, monetary policy influence on the long end of the term structure is much less volatile compared to the short end. While the three-month Treasury bill rate almost doubled during 1998, the ten-year Treasury bond increased from 5,30% to 5,43%. The term spread dropped from plus 1.43 to minus 2.27, which is the largest inversion in our sample. A large drop in the oil price during the extension of the Asia-crisis combined with an increasing wage

[43] From lecture in "krakk & kriser" fall 2006: ASIA-KRISEN. 01.11.06 by Ola H. Grytten.

growth and a monetary policy target of a stable exchange rate forced Norges Bank to increase ‘folio-renten’.[44]

- There never was a recession in Norway at the time, at least not in the way we have define a recession. The model fails in this period, because of international circumstances and a monetary policy determined to target a stable exchange rate. Real GDP growth stayed over trend growth the whole period. However, the definition of an economic downturn is important for the outcome. For instance, the Norwegian stock market fell by almost 50% in 1998, although it quickly recovered.

A common feature between the two ‘false’ signals is that both signals turn up in periods with international currency turmoil. This indicates that the Norwegian term structure is strongly influenced by international term structures. And support that we include international term spreads and consider country specific factors when we study how the term structure can predict real economic activity.

Before the two first recessions in our sample the recession probability increases. However, the whole period is characterized by high recession probabilities and the two increases is rather small compared to the overall level of the probabilities. The information the term structure would have provided in this period is therefore limited. On the other hand, in the quarters preceding the last two recessions in our sample, it seems plausible that the term structure have contained information on the business cycle. This period generally has low recession probabilities except during financial turmoil such as in 1998 and our two recessions.

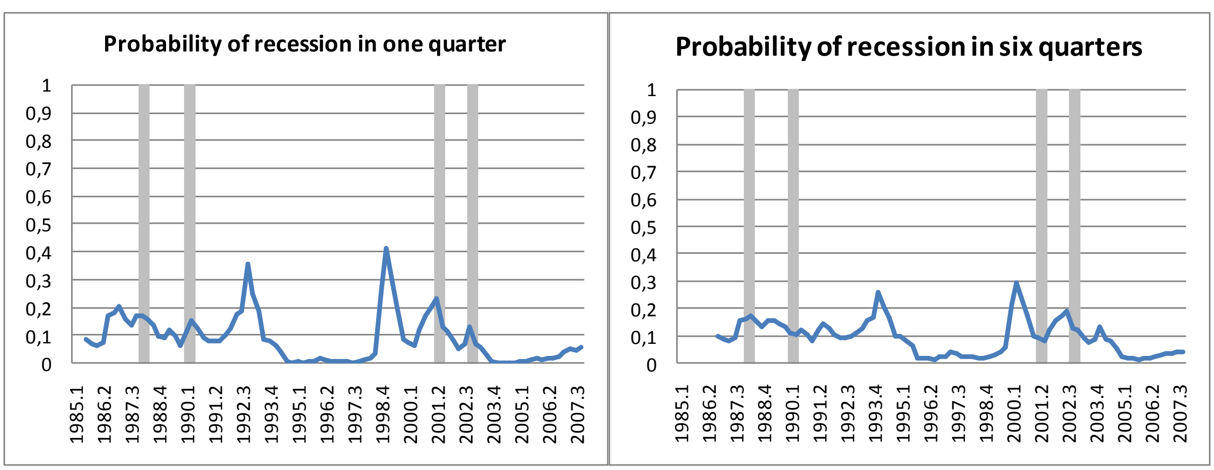
A recession in quarter k.

The model we just discussed, where we find probability of a recession within the next k quarters, is ‘forward-looking’. This means that it uses the term spread today to predict the future. The model we discuss now is different, because the model produce probabilities of a recession today that is the result of the term spread k quarters ago.

[44] Norges Bank: Finansiell stabilitet andre halvår 1998: http://www.norges-bank.no/upload/import/front/rapport/no/fs/1998-02/fs-1998-02.pdf

The probability graphs in figure 7.4 show the estimated probabilities of a recession in one and six quarters. The probabilities are calculated using the coefficient estimates in table 7.2. As we observe in the graphs, the probabilities seems qualitatively similar except that the peaks seems to come around five quarters later in the graph that show the recession probabilities six months ahead compared to the graph that show the recession probability one quarter ahead. This is because the graph that predicts the probability one quarter ahead is calculated using the term spread one quarter earlier and the graphs that predict the probability six quarters ahead is calculated using the term spread six quarters earlier. So, when we get a high probability of a recession in the third quarter in 2000 in the graph that predicts probability of a recession six quarters ahead, it is because this probability is based on the inverted term structure six quarters earlier in the fourth quarter in 1998.The same goes for the high probability of recession in one quarter in the first quarter 1999; it is based on the high negative term spread in the fourth quarter 1998. The peaks in the recession probability graph are based on the same term spread, and displace the recession signals in as we increase the horizon.

FIGURE 7.4: PROBABILITY OF RECESSION IN ONE AND SIX QUARTERS, NORWEGIAN TERM SPREAD ALONE



Source: Authors own calculations.

Because the model is backward-looking, it is most appropriate to use the model to find which lag of the term spread that contains most information about future business cycles. However, we should be aware of how we interpret the results. In example the relative high pseudo r-squared after eight and ten quarters needs to be commented. The reason that these horizons have such a high explanation power is probably a coincident. If the domestic term spread contains most information on business cycles two and a half year ahead, this would certainly expand the horizon to most market participants. The graphs in figure 7.4 shift qualitatively one quarter to the right as we increase the horizon by one quarter. If we increase the horizon to ten quarters, the high negative term spread in 1998 is concurrent with the recession in the second and third quarter in 2001. Therefore we should be careful to put too much attention on the pseudo r-squared when we estimate probit models with varying horizons in on specific quarter.

To summarize the domestic spread:

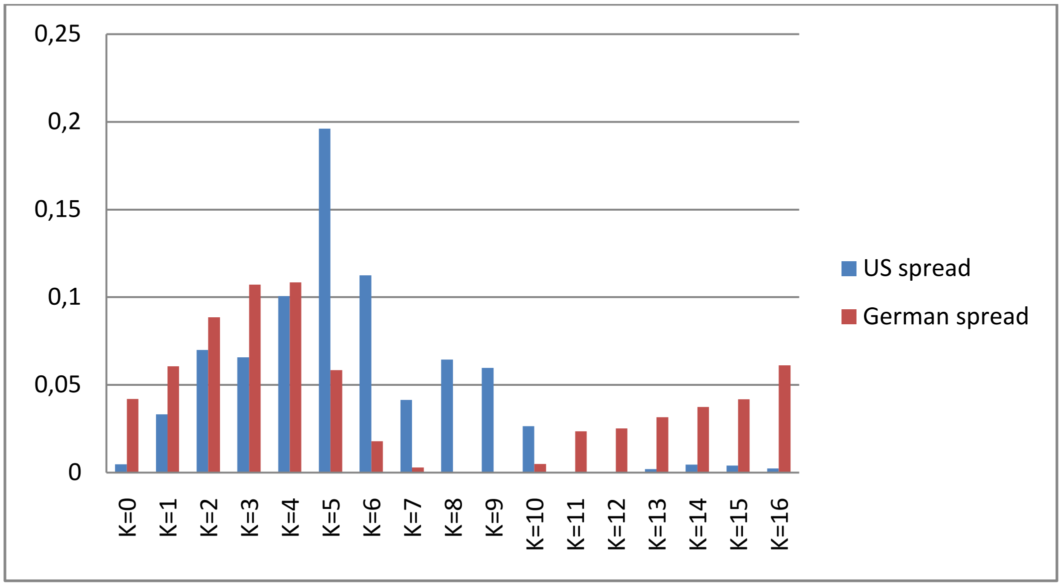
- Has some explanatory power over extreme values of GDP change or recessions. The estimated coefficients are in the expected direction according to theory.
- Explanatory power depends on how a recession is defined.
- Reacts to other factors that are not included in our model. The peak in predicted probability in 1998 quarter four and 1992 quarter three is associated with reasons that don't depend on our definition of a recession.
- Depends on whether the estimated effect is assumed to be forward- or backward looking. While the in-k-quarters models is best suited to determine on which horizon the term spread best explains the variations in the recession variable, the within-k-quarters models is best suited to predict recessions. But the latter depends on the horizon being rather short in order to achieve the sufficient accuracy.

7.4.3 Probit models with domestic and foreign term spreads

After observing that there exists a relationship between the domestic spread and the real economy, we examine the possible influence of the international term spreads upon the Norwegian real economy. This part of the analysis seeks to answer the following questions: Which foreign term spreads are relevant for the Norwegian real economy? And if any foreign term spreads can be isolated that affect the Norwegian real economy more than others; does it bring any additional information to the real economic development than the domestic term spread alone?

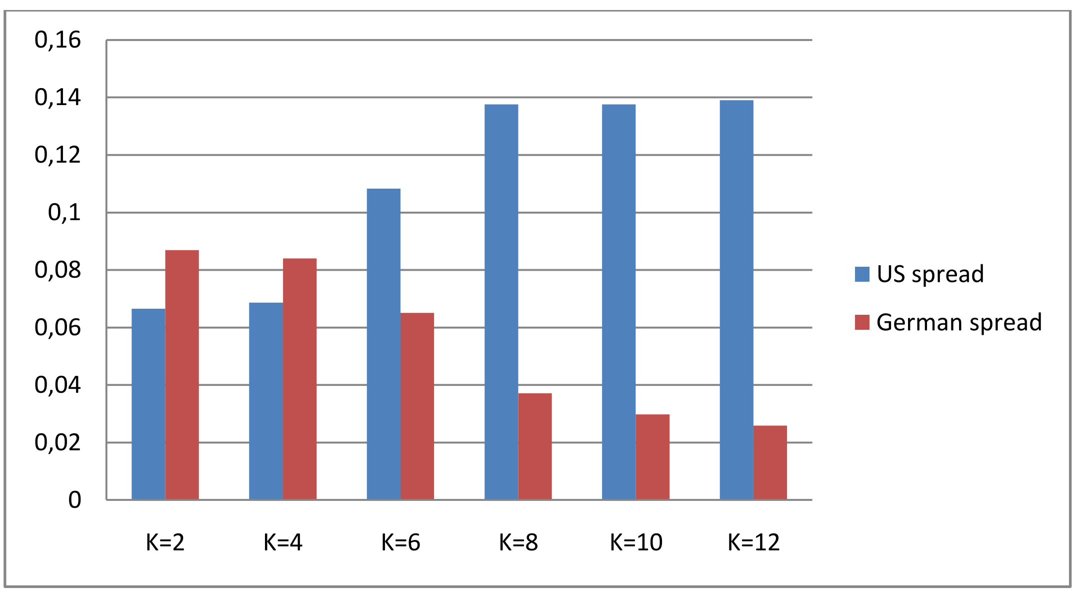
To answer these questions we compare the models with both domestic and foreign spreads with each other, and we compare these models to the ones including only the domestic spread. But first, consider figure 7.5, 5.6 and the models reported in appendix 12.6, which only regress the recession dummy on the US and German term spreads alone. First note that both foreign term spreads have some, but limited explanatory power with respect to the recession dummy. In the in-k-quarters models, the reported pseudo r-squared for the German term spread are highest using two through four quarters. This is also true for the model using within k quarters. The US term spread appear to have some explanatory power over longer horizons compared to the German term spread. It performs particularly well predicting recessions in 5 quarters. As expected, there is no clear pattern regarding the significance of the variables, which imply that the foreign term spreads perform poorly alone. However, the small explanatory power could hold interesting supplementary information for the domestic term spread in predicting recessions.

FIGURE 7.5: PSEUDO R SQUARED FOR THE US AND GERMAN TERM SPREAD – RECESSION IN K QUARTERS



Source: Authors own calculations.

FIGURE 7.6: PSEUDO R SQUARED FOR US AND GERMAN TERM SPREAD – RECESSION WITHIN NEXT K QUARTERS



Source: Authors own calculations.

Next, consider the probit model including domestic and US term spread reported in table 7.3 on the next page. The pseudo r-squared for the recession in-k-quarters models are highest when the horizon is two, six and eight quarters. For models that estimate recession within-k-quarters, the pseudo r-squared increase with k. This is only natural because increased k implies a relaxed accuracy in the forecast. The estimated coefficients on the domestic term spreads are generally higher than the US term spread coefficients, which implies that the domestic term spread contributes more to the probability estimates from a certain level on the term spread. Assuming a zero US spread, an inverted 1% Norwegian term spread would give a 22% probability of a recession in six quarters. Conversely, by assuming a zero domestic spread, an inversion by 1% on the US term spread would only give a 17% probability[45].Also notice that all the constant terms are significant at 1% level in the in-k-quarters models, but the US term of the equation is generally insignificant even at the 10% level, except for the longer horizons in the within-k-quarters models. This is due to the high standard errors reported, which can imply that the US term spread is a poor fit for the Norwegian recessions. Note that we report an extremely high estimate on the US term spread lagged zero quarters in the recession in-k-quarters models. We consider this an anomaly, since nothing in the data and theory imply that such an estimate are reasonable.

[45] NORMSDIST(-1.09+(-0.13*0)+(-0.32*-1))=0.2207 and NORMSDIST(-1.09+(-0.13*-1)+(-0.32*0))=0.1685.

TABLE 7.3: PSEUDO R SQUARED AND Z-STATISTICS FOR PROBIT MODELS USING DOMESTIC AND US TERM SPREADS, RECESSION IN AND WITHIN QUARTER K

	Number of quarters (k) ahead						
	0	2	4	6	8	10	12
Recession in quarter k							
Pseudo – R^2	0.0818	0.1265	0.0796	0.0802	0.1759	0.1702	0.0486
Domestic spread	-0.35(0.19)	-0.47(0.22)	-0.32(0.19)	-0.32 (0.19)	-0.52 (0.24)	-0.60 (0.27)	-0.20 (0.19)
Z – value	-1.82 (0.069)*	-2.16 (0.30)	-1.68 (0.092)*	-1.67 (0.094)*	-2.12 (0.034)**	-2.25 (0.025)**	-1.07 (0.287)
US spread	10.97(16.85)	-0.08 (0.16)	-0.13 (0.16)	-0.15 (0.18)	-0.24 (0.19)	-0.06 (0.17)	-0.16 (0.18)
Z – value	0.65 (0.515)	-0.53 (0.593)	-0.78 (0.434)	-0.81 (0.418)	-1.26 (0.207)	-0.32 (0.750)	-0.87 (0.384)
Constant	-1.51 (0.36)	-1.22 (0.32)	-1.09 (0.32)	-1.05 (0.34)	-1.00 (0.36)	-1.31 (0.40)	-1.07 (0.35)
Z – value	-4.20 (0.000)***	-3.77 (0.000)***	-3.41 (0.001)***	-3.09 (0.002)***	-2.75 (0.006)***	-3.29 (0.001)***	-3.08 (0.002)***
Log likelihood	-24.79	-23.42	-24.50	-24.30	-21.60	-21.58	-22.41
Recession within quarter k							
Pseudo – R^2		0.1349	0.1599	0.1975	0.2431	0.3320	0.3697
Domestic Spread		-0.50 (0.19)	-0.53 (0.16)	-0.56 (0.15)	-0.61 (0.15)	-0.78 (0.17)	-0.87 (0.20)
Z – value		-2.63 (0.009)***	-3.29 (0.001)***	-3.79 (0.000)***	-4.17 (0.000)***	-4.50 (0.000)***	-4.38 (0.000)***
US spread		-0.04(0.15)	-0.12(0.13)	-0.20(0.14)	-0.26(0.14)	-0.36(0.15)	-0.49(0.17)
Z – value		-0.26 (0.791)	-0.86 (0.388)	-1.45 (0.148)	-1.84 (0.066)*	-2.33 (0.020)**	-2.81 (0.005)***
Constant		-1.04(0.30)	-0.51(0.27)	-0.07(0.28)	0.25 (0.29)	0.64 (0.33)	1.07 (0.39)
Z – value		-3.50 (0.000)***	-1.86 (0.062)*	-0.25 (0.800)	0.86 (0.392)	1.93 (0.053)*	2.75 (0.006)***
Log likelihood		-30.45	-39.41	-42.64	-41.89	-37.17	-34.08

Z-statistics; *, ** and *** denote significance at the 10%, 5% and 1% level respectively. The estimated coefficients are reported together with the standard errors in parenthesis. The p-value of the coefficients is reported in parenthesis behind z-value.

TABLE 7.4: PSEUDO R SQUARED AND Z-STATISTICS FOR PROBIT MODELS USING DOMESTIC AND GERMAN TERM SPREADS, RECESSION IN AND WITHIN QUARTER K

	Number of quarters (k) ahead						
	0	2	4	6	8	10	12
Recession in quarter k							
Pseudo – R^2	0.1102	0.1234	0.0719	0.0977	0.2688	0.2629	0.0889
Domestic spread	-0.45 (0.21)	-0.49 (0.22)	-0.36 (0.20)	-0.43 (0.21)	-0.79 (0.28)	-0.82 (0.29)	-0.37 (0.21)
Z – value	-2.19 (0.028)**	-2.20 (0.028)**	-1.79 (0.074)*	-2.09 (0.037)**	-2.86 (0.004)***	-2.81 (0.005)***	-1.79 (0.074)**
German spread	0.27 (0.20)	0.07 (0.19)	0.09 (0.20)	0.27 (0.22)	0.58 (0.25)	0.49 (0.24)	0.37 (0.24)
Z – value	1.37(0.172)	0.34(0.730)	0.46(0.648)	1.23(0.218)	2.28(0.022)**	2.05(0.040)**	1.55(0.121)
Constant	-1.65 (0.33)	-1.42 (0.30)	-1.40 (0.31)	-1.63 (0.36)	-2.21 (0.49)	-2.09 (0.46)	-1.83 (0.42)
Z – value	-4.96 (0.000)***	-4.78 (0.000)***	-4.55 (0.000)***	-4.50 (0.000)***	-4.51 (0.000)***	-4.56 (0.000)***	-4.40 (0.000)***
Log likelihood	-23.94	-23.50	-24.70	-23-84	-0.1917	-19.17	-21.46
Recession within quarter k							
Pseudo – R^2		0.1445	0.1642	0.2100	0.3042	0.4591	0.5199
Domestic Spread		-0.55 (0.20)	-0.59 (0.17)	-0.69 (0.16)	-0.89 (0.18)	-1.35 (0.26)	-1.73 (0.37)
Z – value		-2.80 (0.005)***	-3.48 (0.001)***	-4.22 (0.000)***	-5.01 (0.000) ***	-5.14 (0.000) ***	-4.85 (0.000) ***
German spread		0.15 (0.17)	0.17 (0.16)	0.30 (0.16)	0.54 (0.18)	0.89 (0.23)	1.17 (0.29)
Z – value		0.86 (0.390)	1.07 (0.287)	1.83 (0.068)*	3.03 (0.002)***	3.86 (0.000)***	4.06 (0.000)***
Constant		-1.26 (0.27)	-0.88 (0.24)	-0.73 (0.24)	-0.79 (0.26)	-0.89 (0.28)	-0.90 (0.30)
Z – value		-4.66 (0.000) ***	-3.62 (0.000) ***	-3.00 (0.003) ***	-3.09 (0.002) ***	-3.15 (0.002) ***	-2.99 (0.003) ***
Log likelihood		-30.11	-39.20	-41.97	-38.50	-30.10	-25.96

Z-statistics; *, ** and *** denote significance at the 10%, 5% and 1% level respectively. The estimated coefficients are reported together with the standard errors in parenthesis. The p-value of the coefficients is reported in parenthesis behind z-value.

By substituting the US term spread with the German, the results in table 7.4 are obtained. Compared to the model with the domestic and US term spread, it is clear that the estimates on the domestic term spread coefficients improve markedly. They are all significant different from zero at 1% level for the within-k-quarters models, and significant at either 10-, 5- or 1% level for the in-k-quarter models. What may come across as a surprise, are the positive estimates on the German term spread. By setting the Norwegian term spread to zero, the level of the German term spread consistent with a given probability of recession can be obtained. Comparing the level of both the Norwegian (setting the German term spread to zero) and German (setting the Norwegian term spread to zero) term spread needed for a 90% probability of recession, yields the spread levels -2.7% and -1.35% respectively[46]. It's clear that the larger the estimated spread coefficient, the smaller the term spread needed for the model to give a recession signal. And the more volatile recession probability curve. Letting the German term spread coefficient alone produce recession signals would thus increase the risk of observing false signals. By looking at the data, we observe that the German term spread between ten-year and one-year government bonds haven't been inverted since the first quarter of 1993. This is probably the reason underlying the positive estimates. A recession in Norway may not be associated with an inverted German term spread k quarters before; it's a result of a smaller, but non-negative, German term spread k quarters before. So, if a smaller inversion is needed for a recession signal, such an inversion may in fact be a very strong signal according to our model. Especially when we consider the relatively small amount of observed German inversions. Even though not all of the estimated German term spread coefficients are significantly different from zero, they still contain some information regarding the state of the Norwegian real economy when interpreted along with the other estimated coefficients.

Table 7.5 on the following page provides the estimates of the probit models using domestic, German and US term spread observations. Comparing these results to the other models it is clear that this model contain fewer significant estimates, including the constant term. The estimates on the domestic term spread remain relatively unaffected by the inclusion of two foreign term spreads; they are all significant different from zero at either 10-, 5- or 1% level and generally smaller (more negative) than the estimates on the foreign term spreads. None of the US term spreads are significant different from zero, and the German term spreads

[46] (NORMSINV(0,9)-(0,3))/-0,73 = -1,3446 and (NORMSINV(0,9)-(-0,69))/-0,73 = -2,7008.

generally come out equally significant compared to the model using only domestic and German term spread. What are more concerning are the constant terms, where only two terms are significant in the within-k-quarters model.

TABLE 7.5: PSEUDO R SQUARED AND Z-STATISTICS FOR PROBIT MODELS USING DOMESTIC, US AND GERMAN TERM SPREADS, RECESSION IN AND WITHIN QUARTER K

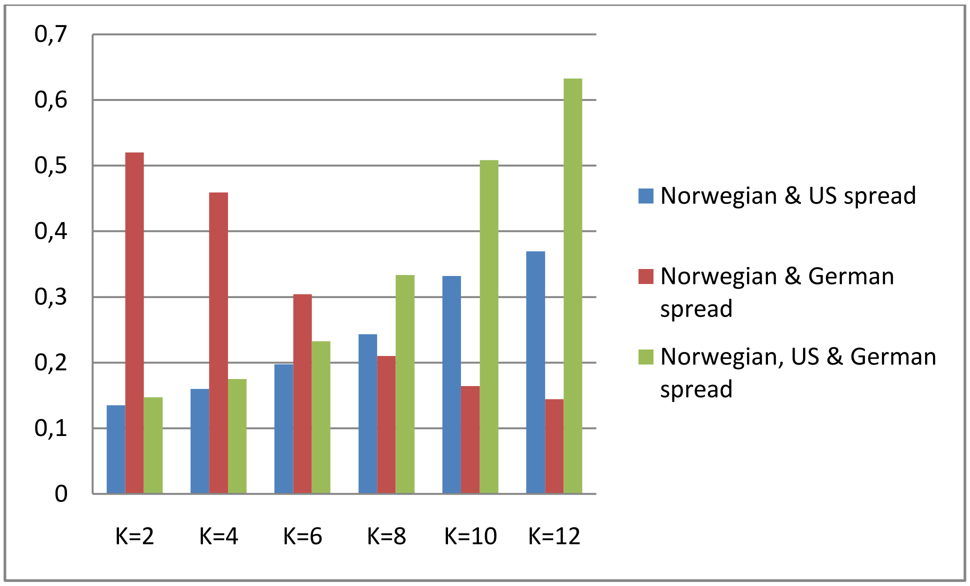
	Number of quarters (k) ahead						
	0	2	4	6	8	10	12
Recession in quarter k							
Pseudo – R^2	0.1136	0.1305	0.0855	0.1122	0.3446	0.2705	0.1110
Domestic spread	-0.45(0.21)	-0.50(0.22)	-0.36(0.20)	-0.43(0.21)	-0.84 (0.28)	-0.80 (0.29)	-0.37 (0.21)
Z – value	-2.18 (0.030)**	-2.24 (0.025)**	-1.78 (0.075)*	-2.07 (0.039)**	-2.96 (0.003)***	-2.82 (0.005)***	-1.74 (0.082)*
German spread	25.96(0.20)	0.09 (0.20)	0.12 (0.21)	0.29 (0.23)	0.94 (0.44)	0.53 (0.26)	0.41 (0.26)
Z – value	1.29 (0.197)	0.46(0.649)	0.56(0.579)	1.25(0.210)	2.14(0.032)*	2.02(0.043)**	1.58(0.114)
US spread	7.75 (18.10)	-0.10(0.17)	-0.14(0.17)	-0.17(0.20)	-0.58 (0.36)	-0.13 (0.21)	-0.21 (0.21)
Z – value	0.43 (0.668)	-0.61 (0.542)	-0.84 (0.401)	-0.86 (0.392)	-1.61 (0.106)	-0.61 (0.539)	-0.99 (0.323)
Constant	-1.76 (0.43)	-1.29(0.36)	-1.20(0.38)	-1.39(0.45)	-2.01 (0.63)	-1.93 (0.52)	-1.58 (0.49)
Z – value	-4.08 (0.000)***	-3.57 (0.000) ***	-3.15 (0.002) ***	-3.10 (0.002) ***	-3.21 (0.001) ***	-3.67 (0.000) ***	-3.22 (0.001)***
Log likelihood	-23.85	-23.31	-24.34	-23.45	-17.18	-18.97	-20.94
Recession within quarter k							
Pseudo – R^2		0.1472	0.1751	0.2323	0.3335	0.5082	0.6326
Domestic Spread		-0.56(0.20)	-0.60(0.17)	-0.70(0.16)	-0.88 (0.18)	-1.42 (0.28)	-2.40 (0.56)
Z – value		-2.82 (0.005)***	-3.52 (0.000)***	-4.22 (0.000)***	-4.95 (0.000)***	-5.05 (0.000)***	-4.27 (0.000)***
US spread		-0.07(0.15)	-0.14(0.14)	-0.21(0.14)	-0.26 (0.14)	-0.37 (0.16)	-0.71 (0.23)
Z – value		-0.43 (0.666)	-1.00 (0.317)	-1.52 (0.129)	-1.77 (0.077)*	-2.26 (0.024)**	-3.07 (0.002)***
German spread		0.16 (0.18)	0.19 (0.17)	0.31 (0.17)	0.54 (0.18)	0.90 (0.24)	1.53 (0.41)
Z – value		0.92 (0.358)	1.18 (0.239)	1.88 (0.060)*	2.99 (0.003)***	-3.75 (0.000)***	3.72 (0.002)***
Constant		-1.18(0.34)	-0.69(0.31)	-0.41(0.33)	-0.38 (0.35)	-0.29 (0.40)	0.08 (0.47)
Z – value		-3.52 (0.000) ***	-2.20 (0.028)**	-1.25 (0.213)	-1.08 (0.281)	-0.72 (0.473)	0.16 (0.872)
Log likelihood		-30.02	-38.69	-40.79	-36.88	-27.36	-19.86

Z-statistics; *, ** and *** denote significance at the 10%, 5% and 1% level respectively. The estimated coefficients are reported together with the standard errors in parenthesis. The p-value of the coefficients is reported in parenthesis behind z-value.

7.4.4 Which of the foreign term spreads contain information about the Norwegian real economy?

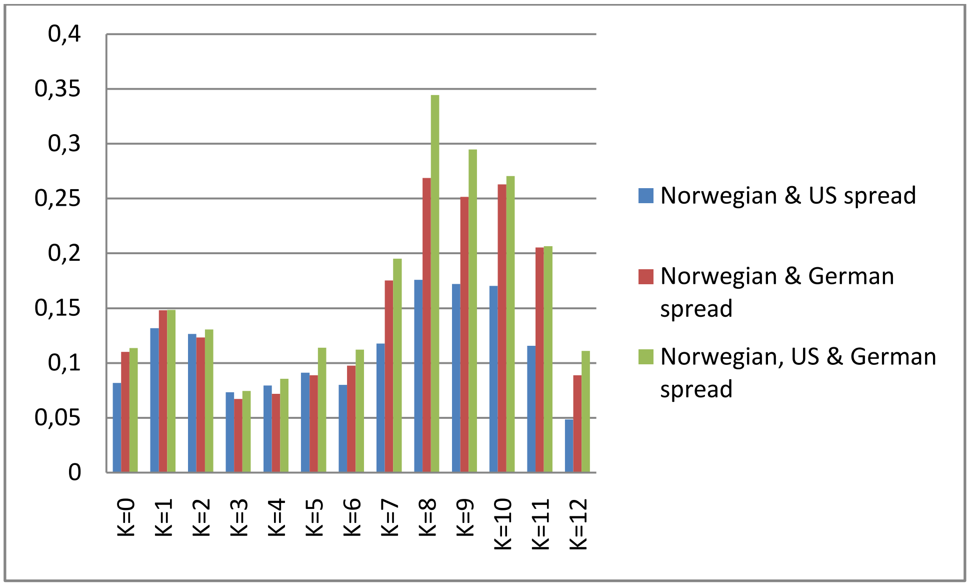
It's clear that individually, the domestic term spread outperforms both the foreign term spreads. However, modeled together, there seems to be some information in both German and US term spreads. But this is a very modest contribution.

FIGUR 7.6: PSEUDO R SQUARED FOR RECESSION WITHIN NEXT K QUARTERS – DIFFERENT FOREIGN TERM SPREADS



Source: Authors own calculations.

FIGURE 7.7: PSEUDO R SQUARED FOR RECESSION IN K QUARTERS – DIFFERENT FOREIGN TERM SPREADS



Source: Authors own calculations.

Figure 7.6 and 7.7 illustrate this fact. Including more variables will always increase the r-squared for most regression models, so judging by this measure alone would be very misleading. Nevertheless, it serves the purpose of a simple comparison between different models with an equal number of variables. Having this in mind, it is clear from the figures that both the German and US term spreads increase the r-squared compared to models with only the domestic term spreads. Since this pattern varies over k quarters, it is obvious that it's not only the inclusion of an extra variable that contributes to this result. Consistent with the previous correlation analysis, the models incorporating the US term spread outperform models without, as the horizon increase in the recession within-k-quarters models. And the models with the German term spread outperform the models without, as the horizon decrease in the recession within-k-quarters models.

The high r-squared's obtained in the recession in-k-quarters models is associated with more uncertainty. They could reflect the true recession picture. If this is the case, the term spread contains remarkably little information about the shorter forecasting horizons. The high r-squared could also be the result of the displacement of the recession probability curve as we change the forecasting horizon k (see discussion below).

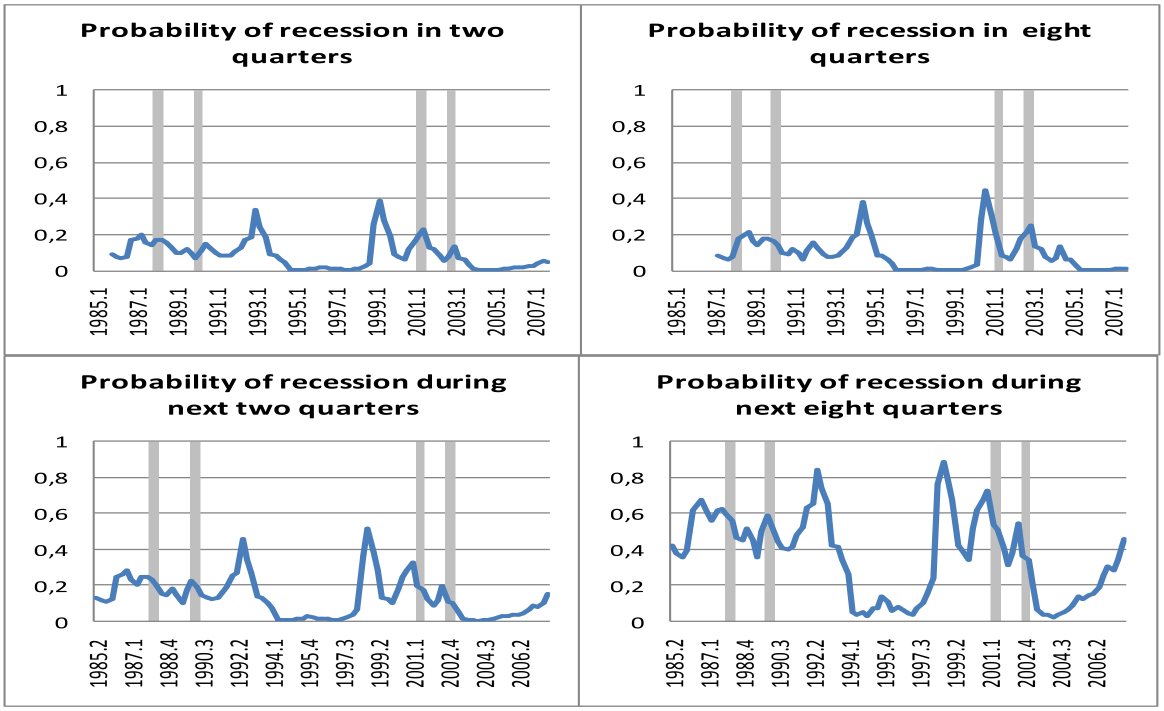
Does the foreign spreads contain additional information?

In order to decide if there's any additional information provided by the foreign term spreads we consider the predicted probabilities in the figures on the following pages. These show the predicted probabilities for recession in and within two and eight quarters respectively for the probit models incorporating domestic and foreign term spreads.

It's clear from the probability graphs that the estimated probabilities increase when we relax the occurrence of a recession from in-k-quarters to recession within-k-quarters. The recession in-k-quarters models seem to shift the probability curve as we change what lag we use on the term spread. This is generally the case for all of the in-k-quarter models, something which makes it crucial for us to check the validity of each predicted recession probability peak against real world experience. It is not plausible that the longer lags of the different term spreads explain real world events equally good as the shorter lagged values of the different term spreads. Apparently the recession within-k-quarter models don't shift the probability curve as we change the horizon for a recession to occur; the peaks all occur in the same quarter when we vary the horizon. This is because the models are forward-looking; they include the term spreads at time t and predict future events, time t,t+k. This methodology makes the predictions more reliable, because the probability peaks are consistent throughout the different models, but less accurate.

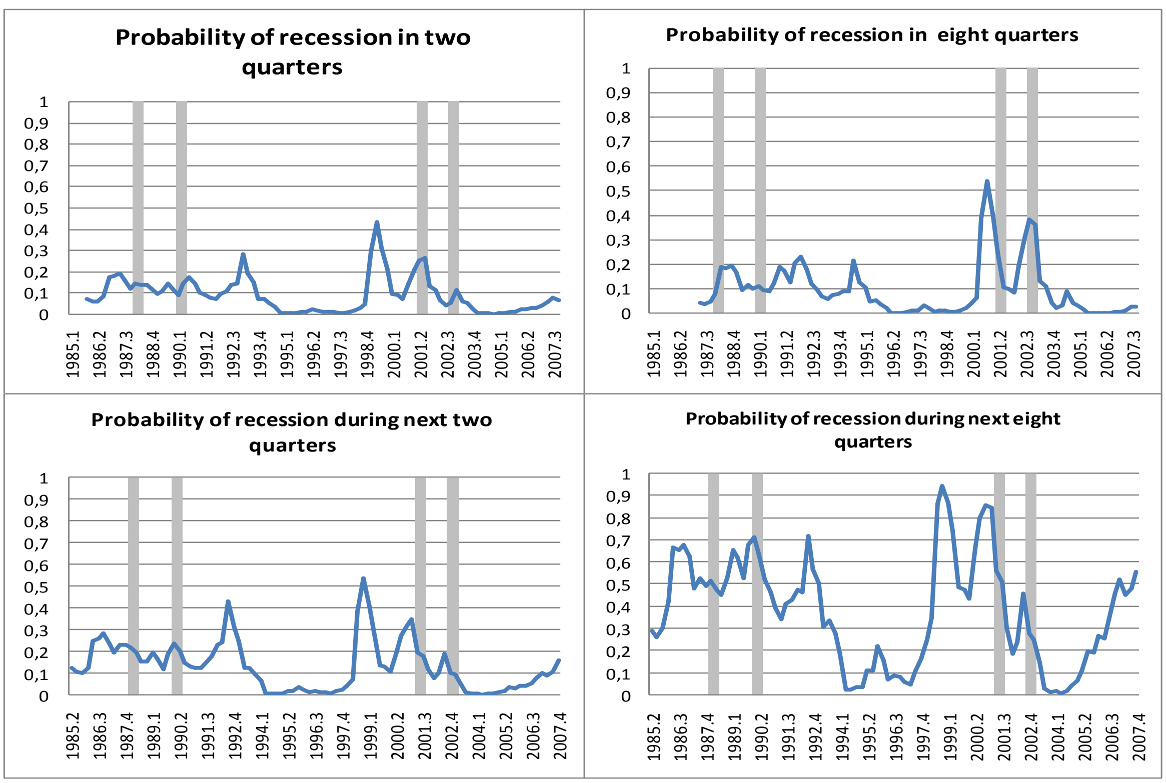
Figure 7.8 - 7.11 show the predicted probabilities of the various models estimating recession in and within two and eight quarters. When comparing the different models that incorporate a foreign term spread, it's apparent that something changes the predicted probabilities compared to when we only use the domestic term spread.

FIGURE 7.8: THE DOMESTIC TERM SPREAD



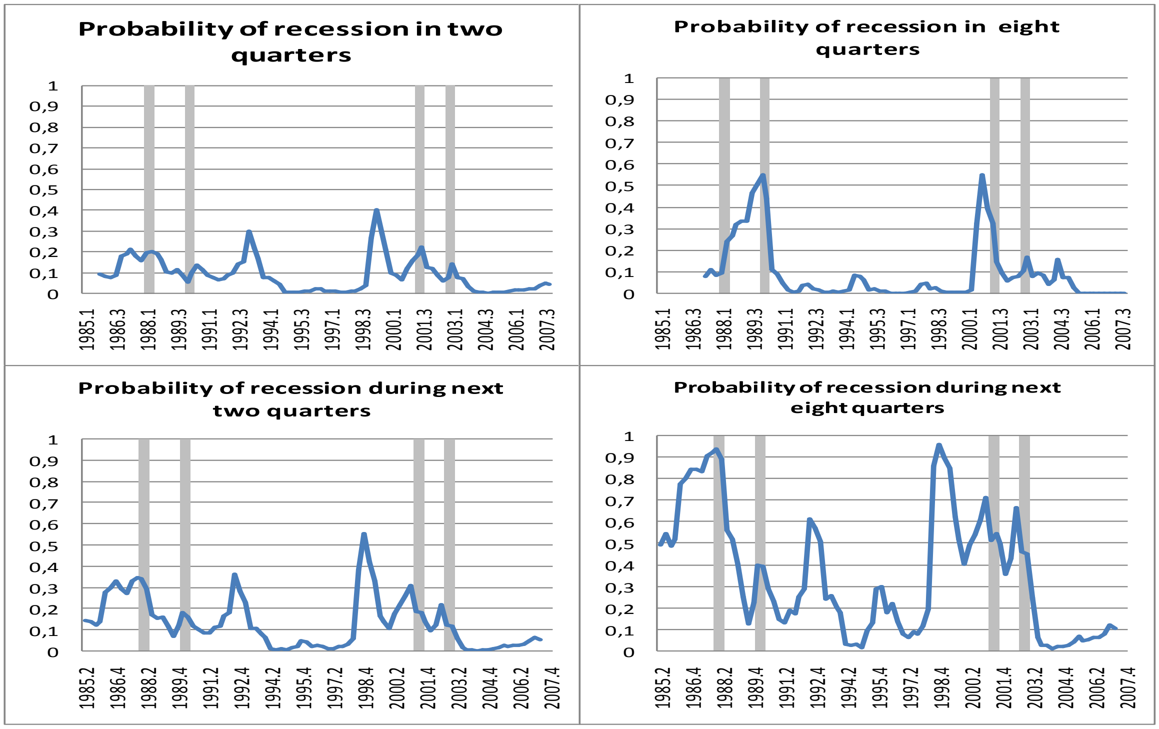
Source: Authors own calculations.

FIGURE 7.9: THE DOMESTIC AND THE US TERM SPREAD



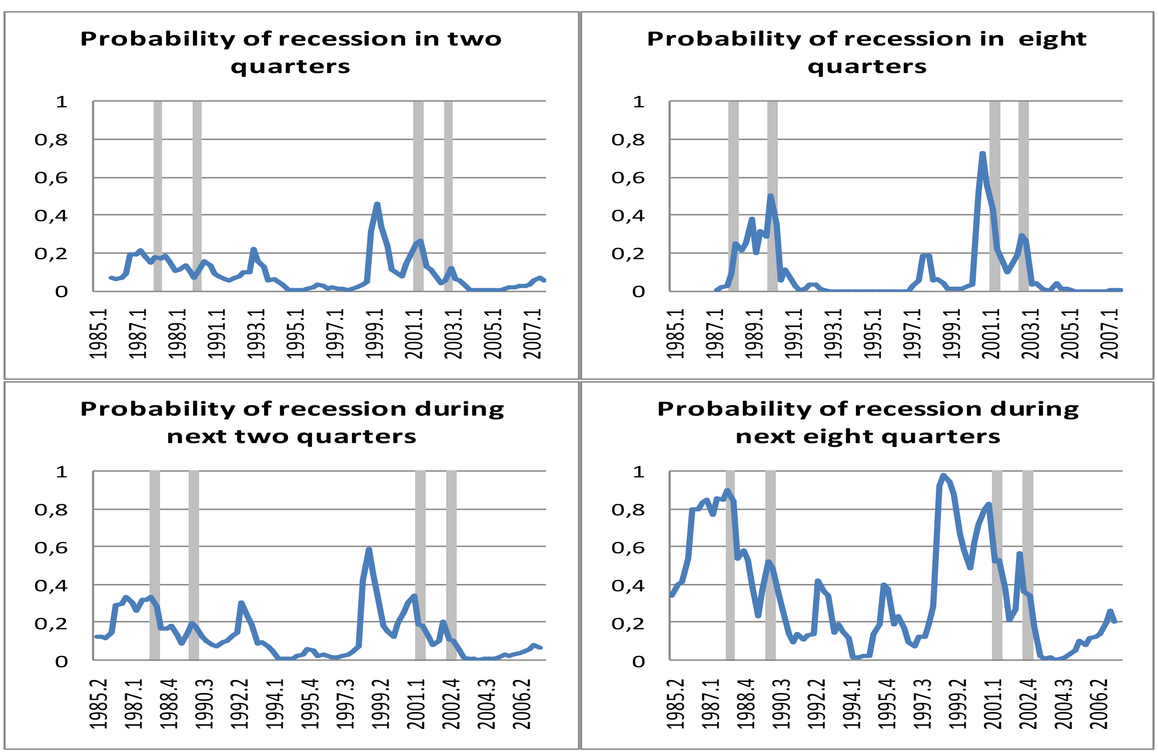
Source: Authors own calculations.

FIGURE 7.10: THE DOMESTIC AND GERMAN TERM SPREAD



Source: Authors own calculations.

FIGURE 7.11: THE DOMESTIC, US AND GERMAN TERM SPREAD



Source: Authors own calculations.

Preferably we want to observe a probability curve that is volatile; the closer the probability are to zero when a recession does not occur in the future quarters the better, and the closer the probability are to one when a recession does occur in the future the better. Thus, if we observe a probability curve that consistently predicts probabilities that vary between 40% and 60% we would be studying very unreliable signals. This is why the term structure has limited information value in the first part of the sample. Even though the probability peaks are concurrent with the dated recessions, the peaks are more distinct in the latter part of the sample. The same is true for the models that use a foreign term spread. Judging by the variability of the predicted probabilities, the models that use some foreign term spread generally yield stronger signals compared to models using domestic term spread alone. That is, they seem to add some more information to the already existing recession probability peaks. However, these models don't give any additional signals compared to the ones only taking account for only the domestic term spread. Consider the peak in 1998 quarter four again. Even the financial crisis behind this peak is registered by the model using the domestic term spread only, but we achieve a clear improvement of this signal by including the US term spread.

To summarize this we conclude that the domestic term spread responds to most of the recessions in the sample. This response is more distinct in the latter half of the sample. Including foreign term spreads improves these responses, but does not give any additional information outside of these probability peaks.

7.4.5 Probit model including domestic term spread and oil investments

In this section, the results of the probit models which estimate the effect of the domestic term spread together with effect of the oil investments are presented. The models are of the same form as the other probit models, and are not given any further consideration. This section examines if controlling for oil investments change the estimated effects of the domestic term spread, and if the oil investments provide any additional information regarding the recessions in Norway.

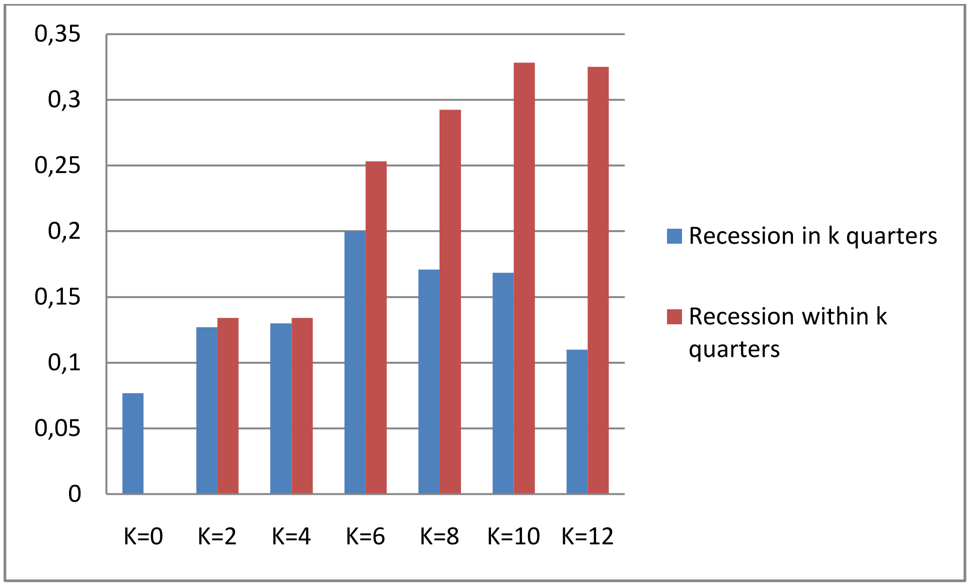
The in-k-quarter models reported in table 7.6 presents estimated coefficients on the term spread that are significant different from zero lagged with two, eight and ten quarters. All of the constant terms are significant different from zero at 1% level. Considering the displacement of the probability curve discussed above, it is plausible to give the shorter lags more weight in the interpretation of the coefficients in the in-k-quarters models. The term spread estimates in the within-k-quarters are all significant different from zero at 1% level, and the coefficients imply that the predicted probabilities of a recession increase as k increase. The effect on the probability of recession that the estimated coefficients yields are qualitatively equal and approximately of the same size as when we estimated the probit model with the domestic term spread alone (see table 7.2). This point is important because it shows that the estimated spread coefficients provide approximately the same information in both models. This means that most of the estimated effects of the domestic term spread coefficients in table 7.2 are the result of the term spread itself and not the result of oil investments. Of course there could be other factors that affect the information content of the term spread which our model doesn't control for, but the results show that controlling for the oil investments doesn't change the separate effect on the response probabilities of the domestic term spread.

TABLE 7.6: PSEUDO R SQUARED AND Z-STATISTICS FOR PROBIT MODELS USING DOMESTIC TERM SPREAD AND OIL INVESTMENTS, RECESSION IN AND WITHIN QUARTER K.

	Number of quarters (k) ahead						
	0	2	4	6	8	10	12
Recession in quarter k							
Pseudo – R^2	0.0767	0.1269	0.1299	0.2000	0.1708	0.1684	0.1100
Domestic spread	-0.35(0.20)	-0.48(0.22)	-0.35(0.20)	-0.40(0.22)	-0.58(0.27)	-0.61(0.27)	-0.27(0.20)
Z – value	-1.80 (0.071)*	-2.15 (0.032)**	-1.73 (0.084)*	-1.81 (0.070)*	-2.19 (0.029**)	-2.28 (0.023)**	-1.36 (0.174)
Oil investments	-0.35(0.90)	-0.58(1.06)	-1.96(1.16)	-3.11(1.32)	-1.22(1.07)	0.11(1.02)	-1.96(1.10)
Z – value	-0.39 (0.697)	-0.54 (0.586)	-1.69 (0.091)*	-2.37 (0.018)**	-1.14 (0.254)	0.10 (0.918)	-1.78 (0.075)*
Constant	-1.31(0.20)	-1.35(0.22)	-1.35(0.22)	-1.46(0.25)	-1.40(0.25)	-1.41(0.25)	-1.40(0.23)
Z – value	-6.61 (0.000)***	-6.20 (0.000)***	-6.20 (0.000)**	-5.74 (0.000)***	-5.56 (0.000)***	-5.59 (0.000)***	-6.20 (0.000)***
Log likelihood	-24.93	-23.41	-23.16	-21.05	-21.74	-21.63	-20.96
Recession within quarter k							
Pseudo–R^2		0.1340	0.1340	0.2532	0.2925	0.3282	0.3252
Domestic Spread		-0.50(0.19)	-0.54(0.17)	-0.62(0.16)	-0.68(0.16)	-0.79(0.17)	-0.08(0.17)
Z – value		-2.62 (0.009)***	-3.29 (0.001)***	-3.89 (0.000)***	-4.32 (0.000)***	-4.64 (0.000)***	-4.71 (0.000)***
Oil investments		-0.09(0.85)	-1.01(0.80)	-2.26(0.84)	-2.39(0.85)	-1.88(0.85)	-1.73(0.86)
Z – value		-0.11 (0.914)	-1.26 (0.207)	-2.68 (0.007)***	-2.81 (0.005)***	-2.21 (0.027)**	-2.01 (0.045)**
Constant		-1.10(0.19)	-0.68(0.17)	-0.39(0.16)	-0.16(0.16)	0.01(0.17)	0.16(0.17)
Z – value		-5.79 (0.000)	-4.12 (0.000)	-2.35 (0.019)**	-1.00 (0.318)	0.07 (0.942)	0.94 (0.346)
Log likelihood		-30.48	-38.96	-39.68	-39.15	-37.38	-36.49

Z-statistics; *, ** and *** denote significance at the 10%, 5% and 1% level respectively. The estimated coefficients are reported together with the standard errors in parenthesis. The p-value of the coefficients is reported in parenthesis behind z-value.

FIGURE 7.12: PSEUDO R SQUARED FOR NORWEGIAN TERM SPREAD AND OIL INVESTMENTS



Source: Authors own calculations

More interesting is the effect of including the oil investments in the probit model. All of the estimated coefficients are negative (except the oil investments lagged ten quarters in the in-k-quarters model), showing the expected direction of the effect on the estimated response probabilities. For a given annual quarterly growth rate, a negative coefficient implies that an increase (decrease) in the oil investments lead to a decrease (increase) in the probability of a recession. This behavior is plausible, given the special importance of the oil sector for the economic development in Norway. The estimated coefficients of the oil investments lagged four and twelve quarters are significant at 10% level, and lagged six quarters they are significant at the 5% level in the in-k-quarters models. We would expect a more significant estimated coefficient when the oil investments are lagged by eight quarters, following the results of the OLS estimation in part 5. The discrepancy between the two results can apply to the differing responses of oil investments to continuous versus extreme measures of real economic activity. In the within-k-quarters models, the coefficient estimates on the oil investments are significant at 1% level at six and eight quarters, and at 5% level at ten and twelve quarters. The oil investments lagged eight quarters are also the strongest rejection of the null hypothesis which state that the oil investments have no effect upon real economic activity. Figure 7.12 show that the pseudo r-squared correspond to the significance pattern of the estimated coefficients. Including the oil investment increase the explanatory power on intermediate term (K=6, K=8 and K=10).

As an example of the different effects of the domestic term spread and oil investments, consider the partial effect of each of the variables assuming the other zero when probability of recession during next two and eight quarters are calculated. The probability of recession within two quarters by assuming the term spread and the growth in oil investments are zero, is 27%and 16% respectively.[47] Within eight quarters the corresponding probabilities are 70% and 99% respectively.[48] This is a very obvious relative increase in the effect of the oil investments as we increase the horizon. Of course we should be careful to put too much weight on the 99% probability of recession. Two years is a very long time. But the relative increase in effects between the two variables show that oil investments contain much more information than the term spread alone regarding our recession measure. Corresponding to these calculations, the inversion in the term spread and negative growth in oil investments needed to signal a recession within next two quarters with 90% probability are -0.36% and -2.02% respectively.[49] For recession during next eight quarters the figures are -1.65% and -0.47% respectively.[50]

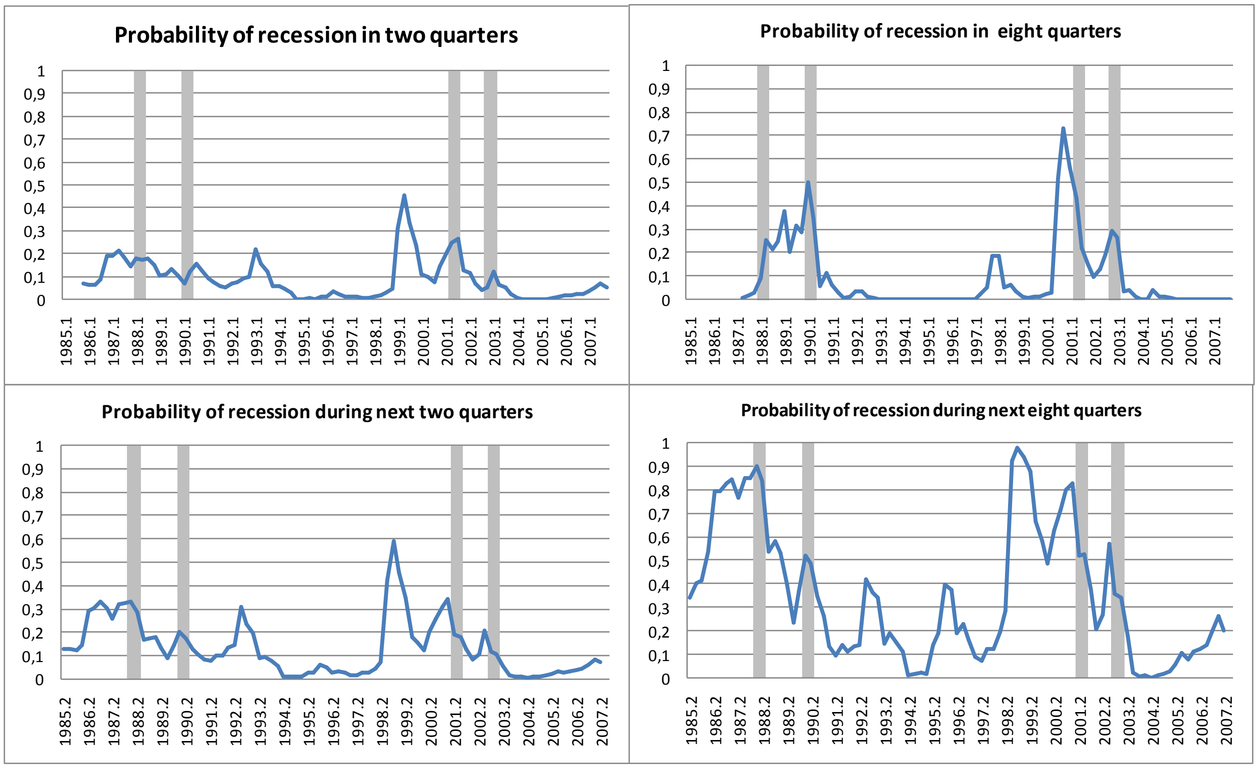
[47] NORMSDIST(-1.1+(-0.5*-1)*(-0.09*0)=0.2743 and NORMSDIST(-1.1+(-0.5*0)+(-0.09*-1)) =0.6985.

[48] NORMSDIST(-0.16+(-0.68*-1)*(-2.39*0)=0.1562 and NORMSDIST(-0.16+(-0.68*0)+(-2.39*-1)) =0.9871.

[49](NORMSINV(0.9)+(-1.1))/(-0.5)= -0.3631 and =(NORMSINV(0.9)+(-1.1))/(-0.09)= -2.01724.

[50] (NORMSINV(0.9)+(-0.16))/(-0.68)= -1.64934 and =(NORMSINV(0.9)+(-0.16))/(-2.39)= -0.4693

FIGURE 7.13: PROBIT GRAPHS USING THE DOMESTIC TERM SPREAD AND OIL INVESTMENTS



Source: Authors own calculations

In the previous section, the probability graphs showed that the foreign term spreads improved the signals provided by the domestic term spread, rather than provide any additional signals. By looking at figure 7.13, it is clear that oil investments have a different effect when we look at the probability graphs for recession within two and eight quarters. We observe that the model predicts approximately equal recession probabilities in the quarters preceding the last two recessions, compared to the model including the domestic term spread only. This imply that the oil investment don't provide any additional information regarding these two peaks. However, regarding the first 'false' signal in 1993, the model including oil investments predicts a lower probability. Regarding the second 'false' signal 1998, the model estimates a higher probability. These differences are within a +/-10% interval. What is more concerning is a 'third' signal in 1995 quarter four, in which it predicts a 5% probability of recession within next two quarters and 40% probability within next eight quarters. Whether this is a recession signal or not, depends on how high the threshold is, on which one bases the judgments of what should be a signal or not. Perhaps this is too modest a signal, but it seems clear that something makes this a more distinct peak, when the oil investments are included. This can support the proposition of some additional information in the oil investments regarding the business cycles of Norway.

8. Out-of-sample forecasting

8.1 Out-of-sample forecasting using the probit models

In this section, we perform out-of-sample-tests using the model that performs best under the in-sample regression. This method performs rolling regressions up to a certain quarter preceding the recession quarter. The last in-sample observation is referred to as the cut-off quarter. In order for the model to perform well out-of-sample, it is crucial to let the model include some observations of recessions. Considering our limited sample, it is necessary to include the first two recessions in the first half of the sample in order to make reliable out-of-sample predictions on the recessions in the last half of the sample. For the out-of-sample predictions, this is a choice between sample-size and information value. Having estimated an in-sample model up to a cut-off quarter, we use the estimated coefficients together with future observations of the term spread to make recession probability estimates. This procedure's strength is that the estimated coefficients represent all the known information *in real time*. The in-sample models estimated before represent all the information available *at any time* in the entire sample. It would therefore imply increased practical information value of the term structure if it reliable predicts recession's out-of-sample over time. The weakness of the procedure is that it is difficult to compare different models with out-of sample fit measures, such as Estrella's pseudo r-squared. In addition, it relies on the sample size.

8.1.1 The results

Based on the assessment of the different probit models in the previous sections, we performed a series of out-of-sample forecasts on the last two dated recessions in the sample; in 2001 quarter two and three, and 2002 quarter four and 2003 quarter one. The method is based on the rolling regressions performed by Estrella & Hardouvelis (1991) and explained in part 6. We chose to include the domestic, German and US term spreads in the models. While none of the foreign term spreads performed stable and consistent throughout the varying horizons, it was difficult to argue for excluding one and not the other. On the one hand, the economic significance of the US term spread and the possible long-term impact upon the Norwegian economy was considered. On the other hand, the economic significance of the German term spread upon the Euro-area and possible impact upon the Norwegian economy on a shorter term (compared to the US term spread) was assessed. We reasoned they supplement each other, while neither perform stable on their own.

Table 8.1, reports the results from the regressions performed in advance of the first recession. Each model observes the various term spreads over time and are cut off at some quarter in advance of the recession quarters. The models are reported according to this cut-off-quarter in the column to the left in the table. Generally, the sign and the size of the estimated coefficients are in line with our estimates in the previous parts. The German term spread stand out with small positive estimates, while the US and Norwegian are negative. The Norwegian term spread is generally more negative than the US term spread. The fact that the recession within-quarter-k models generally contain more significant estimates compared to the recession in-k-quarters models is also in line with the previous models is. The variation in the estimates across different cut-off-quarters is marginal when it comes to the estimated coefficients and their standard errors. Looking at the pseudo r-squared, we see some more variation between different cut-off-quarters for the within-k-quarter models than the in-k-quarter models. This can reflect that the closer the term spread is observed before the recession the more information it provides. The rationale behind this is that more and possible larger (in absolute value) inversions are observed when the cut off quarter is closer to the recession.

Figure 8.1 show the average predicted probabilities of a recession for the different models on the first of the two recessions. This average is taken from the predicted probabilities of recession in- or within-k-quarters models over the different cut-off-quarters for the different models. When we use the term spreads outside the sample, they can be considered as future observations. This is because the models are estimated in a way that they represent the known information up to a certain point in time. Thus, if the predicted probabilities are about equal to the ones estimated in the previous models, this would imply a relatively stable predictive relationship between the two variables. In addition, this would increase the term structures usefulness as a leading indicator.

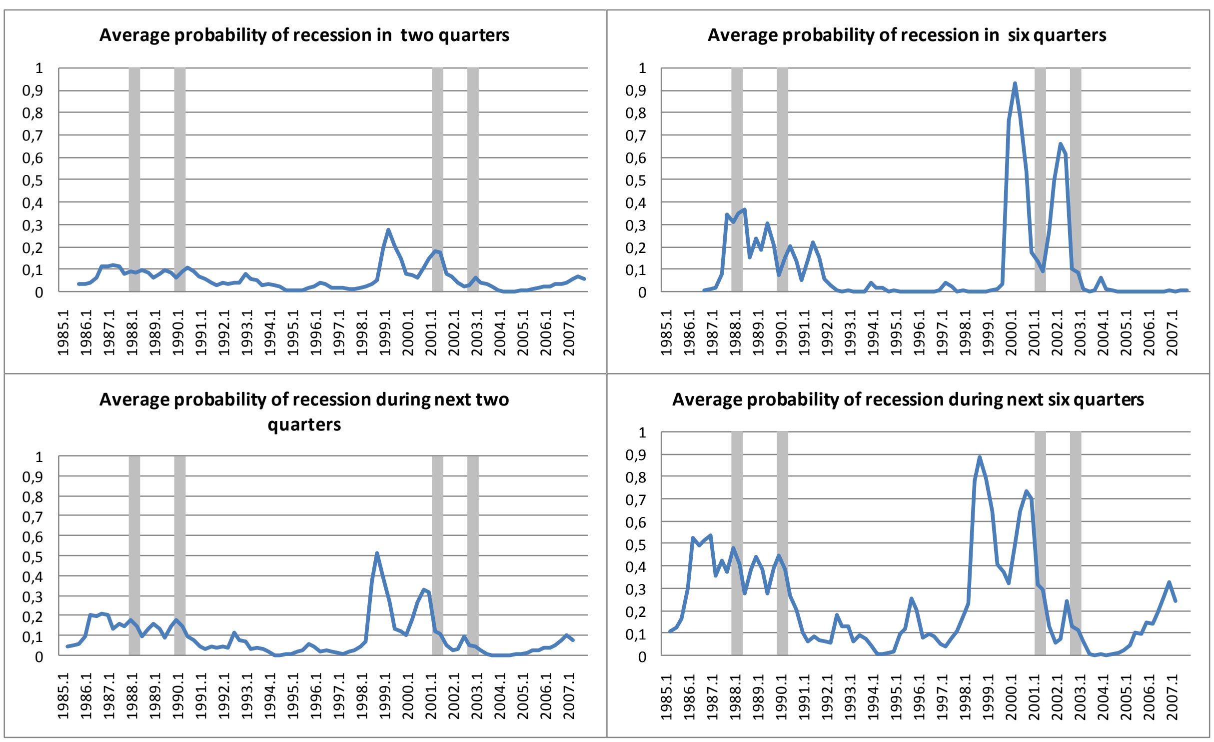
TABLE 8.1: PSEUDO R-SQUARED AND Z-STATISTICS FOR OUT-OF-SAMPLE FORECASTING WITH PROBIT MODELS USING DOMESTIC, US AND GERMAN TERM SPREADS, RECESSION IN AND WITHIN QUARTER K. RECESSION DATED 2001 QUARTER TWO AND THREE

Last observation	Spread NO (β_1)	Spread GER (β_2)	Spread US (β_3)	Constant (β_0)	Pseudo – R^2	Log likelihood
Recession in two quarters						
2000.Q3	-0.34(.27)	0.08(0.23)	-0.17(0.24)	-1.37(0.47)***	0.0692	-13.68
2000.Q4	-0.34(0.27)	0.09(0.23)	-0.16(0.24)	-1.40(0.47)***	0.0657	-13.80
Recession in six quarters						
1999.Q3	-1.07(0.58)*	0.47(0.35)	-0.60(0.45)	-1.21(0.63)*	0.2719	-10.27
1999.Q4	-1.09(0.58)*	0.47(0.35)	-0.60(0.45)	-1.23(0.62)**	0.2735	-10.30
Recession within two quarters						
2000.Q3	-0.44(0.25)*	0.16(0.20)	-0.16(0.21)	-1.31(0.42)***	0.0985	-17.77
2000.Q4	-0.50(0.25)**	0.16(0.21)	-0.26(0.21)	-1.13(0.39)***	0.1355	-19.00
2001.Q1	-0.55(0.25)**	0.16(0.21)	-0.30(0.20)	-1.04(0.39)***	0.1690	-20.04
Recession within six quarters						
1999.Q3	-0.63(0.21)***	0.28(0.18)	-0.34(0.19)*	-0.56(0.56)	0.2074	-25.41
1999.Q4	-0.63(0.20)***	0.30(0.18)	-0.36(0.19)*	-0.50(0.40)	0.2075	-26.51
2000.Q1	-0.62(0.20)***	0.30(0.18)*	-0.39(0.19)**	-0.43(0.39)	0.2042	-27.69
2000.Q2	-0.62(0.20)***	0.30(0.18)	-0.42(0.19)**	-0.34(0.38)	0.2132	-28.40
2000.Q3	-0.63(0.20)***	0.29(0.18)	-0.45(0.19)**	-0.27(0.37)	0.2287	-28.81
2000.Q4	-0.65(0.20)***	0.29(0.18)	-0.47(0.18)***	-0.22(0.36)	0.2468	-29.05
2001.Q1	-0.66(0.20)***	0.29(0.18)	-0.49(0.18)***	-0.19(0.36)	0.2621	-29.33

Z-statistics; *, ** and *** denote significance at the 10%, 5% and 1% level respectively. The estimated coefficients are reported together with the standard errors in parenthesis. The p-value of the coefficients is reported in parenthesis behind z-value.

The overall pattern is similar to the previous models. The predicted probability of a recession in two quarters is however very low, and it would be problematic to use the model to predict the future based on the small peak it shows right before the recession. The in-six-quarters model demonstrates the displacement of the probability curve experienced by the previous models. A bit more rewarding are the within-two- and six-quarters models. It's clear that the within-six-quarters model register both of the coming recessions, although the probability is quite low in front of the second recession. This improves in the within-six-quarters model, due to the reduced accuracy of the prediction. Moving beyond the two recessions it's clear that the forecasts produced by the different models are of limited value.

FIGURE 8.1: AVERAGE PROBABILITIES ESTIMATED FOR THE RECESSION DATED 2001 QUARTER TWO AND THREE



Source: Authors own calculations.

TABLE 8.2: PSEUDO R-SQUARED AND Z-STATISTICS FOR OUT-OF-SAMPLE FORECASTING WITH PROBIT MODELS USING DOMESTIC, US AND GERMAN TERM SPREADS, RECESSION IN AND WITHIN QUARTER K. RECESSION DATED 2002 QUARTER FOUR AND 2003 QUARTER ONE

Last observation	Spread NO (β_1)	Spread GER (β_2)	Spread US (β_3)	Constant (β_0)	Pseudo – R^2	Log likelihood
Recession in two quarters						
2002.Q1	-0.48(0.27)*	0.08(0.23)	-0.33(0.22)	-1.11(0.41)***	0.1575	-16.94
2002.Q2	-0.48(0.28)*	0.08(0.23)	-0.33(0.22)	-1.11(0.41)***	0.1602	-16.97
Recession in six quarters						
2001.Q1	-0.47(0.28)*	0.29(0.27)	-0.12(0.28)	-1.73(0.65)***	0.2719	-12.77
2001.Q2	-1.73(0.26)*	0.31(027)	-0.20(0.27)	-1.53(059)***	0.2735	-15.13
Recession within two quarters						
2002.Q1	-0.55(0.25)**	0.13(0.20)	-0.30(019)	-0.97(0.38)**	0.1641	-22.22
2002.Q2	-0.48(0.23)**	0.11(0.19)	-0.17(0.17)	-1.01(0.37)***	0.1153	-25.26
2002.Q3	-0.50(0.22)	0.13(0.18)	-0.13(0.16)	-1.03(0.37)	0.1107	-27.07
Recession within six quarters						
2001.Q1	-0.66(0.20)***	0.25(0.18)	-0.49(0.18)***	-0.19(0.36)	0.2621	-29.33
2001.Q2	-0.66(0.19)***	0.27(0.18)	-0.48(0.18)***	-0.15(0.36)	0.2572	-30.38
2001.Q3	-0.66(0.19)***	0.27(0.18)	-0.47(0.18)***	-0.12(0.36)	0.2507	-31.48
2001.Q4	-0.65(0.19)***	0.27(0.18)	-0.40(0.17)**	-0.16(0.35)	0.2268	-33.32
2002.Q1	-0.61(0.18)***	0.26(0.17)	-0.32(0.16)*	-0.22(0.35)	0.1937	-35.60
2002.Q2	-0.60(0.18)***	0.26(0.17)	-0.27(0.15)*	-0.27(0.35)	0.1735	-37.34
2002.Q3	-0.61(0.18)***	0.27(0.17)	-0.24(0.15)	-0.29(0.35)	0.1721	-38.23

Z-statistics; *, ** and *** denote significance at the 10%, 5% and 1% level respectively. The estimated coefficients are reported together with the standard errors in parenthesis. The p-value of the coefficients is reported in parenthesis behind z-value.

Table 8.2, shows the same as table 8.1, the only difference is that the models are estimated in advance of the second recession. The results are similar to the ones estimated on the previous recession. The main difference is the variability across models that use different cut-off-quarters for the recession-in- and within-six-quarters models. For these models, the estimated coefficients on the domestic and US term spread and pseudo r-squared fall, as the closer the cut-off-quarter are to the dated recession quarter. All, while the standard errors remain relatively unchanged, resulting in estimates on the US term spread that are not significant different from zero. In addition, the German term spread coefficients increase as the cut off quarter is closing in on the recession quarter. This is a puzzle, when we consider the opposite pattern before the previous recession.

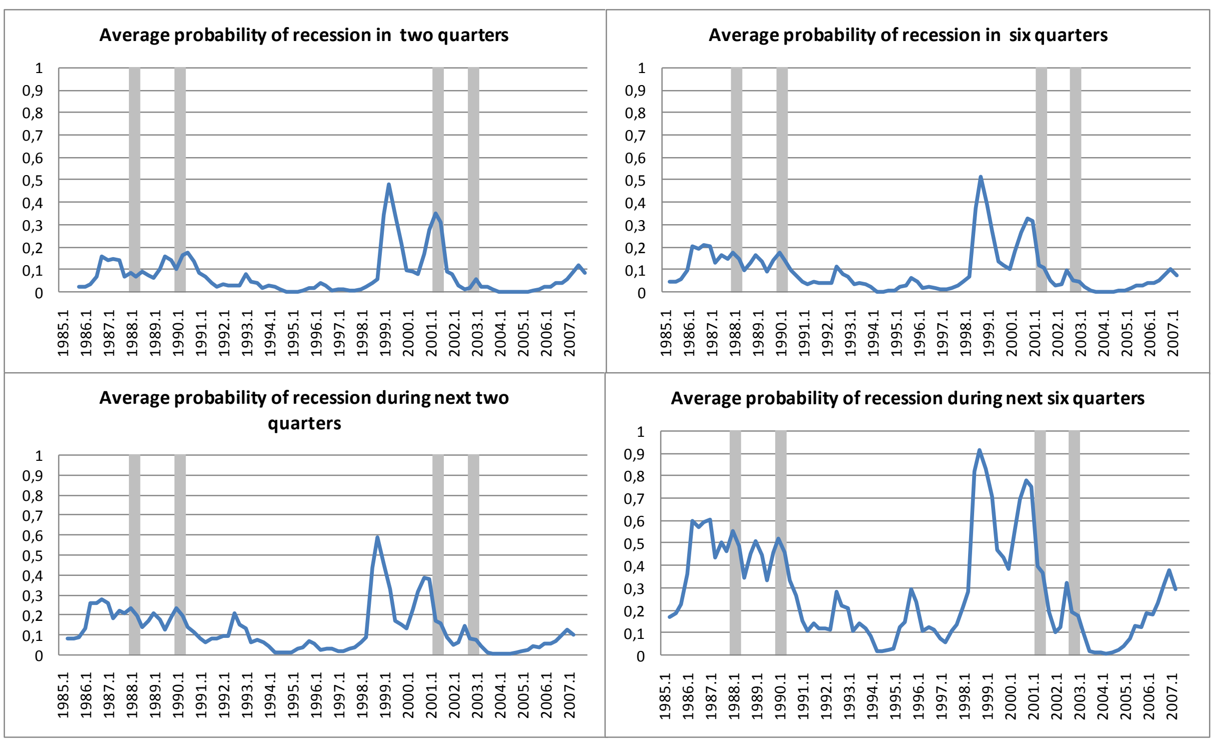
By looking at figure 8.2, we observe that the average predicted probabilities are in fact lower before the last dated recession, compared to the probabilities predicted before the first recession (by the models that cut off before the first recession). The probabilities are 15% and 30% for the within-two- and within-six-quarters models respectively. This matches the lower pseudo r-squared and the lower estimated coefficients in these models. Why does the models predict the last recession poorer than the previous? We should be careful to draw any certain conclusions about this, when considering the low amount of significant coefficients in both regressions. But the poorer results could reflect one of the following points:

- A shift in the predictive ability of one or more of the term spreads used in our study. If this is the case, there should exist some economic factors appearing at the time, which caused the interest rates not to reflect real economic expectations. One possible factor could be the shift to inflation targeting in the Norwegian monetary policy, which could reduce the volatility in the term structure.
- There was no recession. Remember that we use a “rule of thumb” to date recessions. More sophisticated business cycle models could be used to determine whether there was a recession at the time. If this is the case, it could explain the decreasing estimated coefficients of the within-two- and within-six-

quarters models. The higher coefficients in the models with cut-off-quarter closely preceding the recession could be a result of the observed inversions before the previous recession.

- Limited out-of-sample forecasting ability of the term structure in general. While the previous studies conducted in the US report the term structure as a relatively stable indicator over time, the poor performance predicting the last recession could indicate that it's more unreliable in predicting the Norwegian real economic development.

FIGURE 8.2: AVERAGE PROBABILITIES ESTIMATED FOR THE RECESSION DATED 2002 QUARTER FOUR AND 2003 QUARTER ONE



Source: Authors own calculations.

Summary

We saw that the out-of sample forecasting ability resembles the in-sample forecasting ability reported earlier regarding the first recession studied. The predicted probabilities show a similar pattern across the various models. Also in line with the in-sample models are the fact that the within-k-quarter models seem to fit or predict better. Regarding the last dated recession, the pattern alternates for the within-k-quarter models, which report lower and less significant estimates when the cut-off-quarter closes in on the recession quarters. To explain this we proposed three possible explanations.

Regarding the explanations, the one that explains the difference in in-sample and out-of-sample forecasting ability is more plausible. Figure 9.5 in Norges bank's staff memo 2/2005 (Husebo & Wilhelmsen 2005) show that there were in fact a recession at the time, although not a strong one. Thus, a combination of the other two seems to apply to the limited predictive ability on the last recession. More sophisticated models should be used to determine if a regime shift occurred at the time. But consider the Norwegian real interest rate at the time. Compared to other Scandinavian, Euro and US real interest rates, the Norwegian one was higher than all of the above. The rationale behind the higher interest rate was the expected high inflation at the time, when the global economy was in a state of expansive monetary policy fearing a recession several quarters ago. This could cause the folio rate to divert from the market's expectations of real economic development. This would make the term spread an unreliable predictor or indicator at the time. So, the poor performance out-of-sample for the last recession could represent a non-persistent shift in interest rate's expectations qualities, an anomaly you could say. Or it could be seen as a signal of time-varying reliability of the term structure, due to the many considerations in interest rate setting.

8.2 Out-of-sample forecasting using the standard OLS model

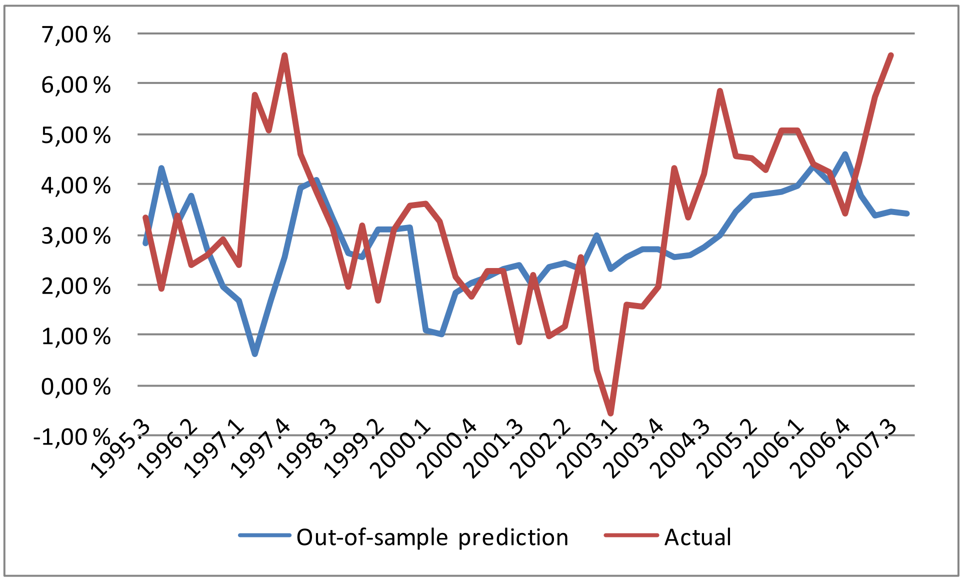
In this section, we estimate overlapping models of ten years, which ensures a minimum of 35 observations in each window. The variables are the same as used in table 5.11-5.13. The estimates from each window are then used to forecast the annual quarterly growth in GDP, in the first quarter succeeding the window period. As usual, the standard errors are corrected using the Newey-West approach (1987)[51]. The estimated windows include a smaller amount of observations compared to the previous OLS estimations, and thus imply that a smaller amount of lags should be corrected for autocorrelation in the overlapping models. This procedure is comparable to the out-of-sample forecasts of the probit models, in the way that the models are estimated in such a manner that they reflect the known information at the time. This information is used to forecast the next annual quarterly GDP growth. It is not comparable to the forecasts of the probit models in the way that the window period is constant at ten years throughout all regressions. Whereas the probit-forecasts used all the known information up to a certain cut-off quarter, the OLS-forecasts use the information from t-1 quarter to t-10 years. This difference underlines the desire to examine changes in the forecasting ability of the model over time. From our previous regressions we expect more information in the term structure in the latter period, and thus, stronger forecasting ability.

Figure 8.3 show the forecasts of the overlapping regressions together with the actual annual quarterly growth in GDP. When comparing the two graphs it is apparent that the OLS model is not a perfect fit for the actual GDP growth. The predictions form a less volatile graph compared to the actual GDP, showing few extreme predictions. In fact, the standard deviations of the prediction and actual GDP series are 0.90% and 1.61% respectively. The average prediction is 2.85%, while actual annual GDP growth is on average 3.25% in the forecast period.

[51] The estimated windows include a smaller amount of observations compared to the previous OLS estimations, and thus imply that a smaller amount of lags should be corrected for autocorrelation in the overlapping models. After estimating the model in the first window and observing that five lags should be corrected, we reason that five lags should be corrected for autocorrelation in each window. This assumption is flawed by the possibility of time varying autocorrelation, but it avoids the workload of observing the autocorrelation in each window. Five lags serve as a reasonable approximation.

This underlines the observed pattern, in which the predictions seem to under-estimate the few extreme peaks in actual GDP growth, forming a less volatile series and an imperfect fit. On average, the overlapping regressions produce out-of-sample forecast that are 0.40% below the actual growth in GDP.

FIGURE 8.3: ANNUAL QUARTERLY GDP GROWTH, OUT-OF-SAMPLE PREDICTION



Source: Authors own calculations.

Furthermore, the model performs worse in the start and last part of the sample. There is two peaks in 97 quarter two and four where the model under-predict the annual GDP growth by -5.14% and -4.00% respectively. This point corresponds to the 'false' signal yield by the probit models following the financial turmoil in Asia. The model performs much better in the middle part of the sample with smaller deviations from the actual GDP growth. This is also the period with relatively stable annual GDP growth. What is more concerning is the period from 2003 and onward towards today, in which there are fewer approximately concurring points between the two series, than mispredictions. This is the period in which the probit forecasts are the most stable.

The findings can be interpreted as evidence against predictive power of the term structure. A more useful interpretation would be instable predictive power. For practical purposes the model produces deviations that are too large to accept in some periods, and smaller deviations in other periods. An on average -0.40% under-prediction suggests that the predictive power exists, but this is not very useful for forecasting when the model predicts large values in the wrong direction in some periods.

A more interesting interpretation could be that the model suffers from a poor predictive ability out of sample when real economic activity changes dramatically in either direction. Comparing the out-of-sample forecasts of the OLS model to the probit model, yields an interesting assessment about the relationship; the term structure seems to predict continuous changes in GDP worse than extremes. The low volatility of the predicted series and the average under-prediction is an indication of this. If this is a valid conclusion, it reduces the term structures suggested structural relationship to real economic activity to an instable reduced form connection. However, as we have seen, the model suffers from co-linearity among the term spreads and there is also reasonable to question the normality of the sample distribution, especially as the sample decrease.

9. Summary and discussion

This section links the results of the quantitative models up to the hypothesis, and scrutinizes the validity of the null hypothesis - there is no information regarding the real economic activity in the term structure. First we summarize our results.

Correlation analysis

The correlations between annual quarterly GDP growth and both the domestic and foreign term spreads are higher in the second subsample (1997-2007) compared to the first subsample (1985-1996). The correlations of foreign term spreads exhibit a pattern that is more in line with expectations from theory and a larger range, compared to the domestic term spread, in the second subsample. The first subsample contains many country specific factors that affect the correlations in the entire sample. It is difficult to say whether the correlations support the null hypothesis or not, because the correlations does not control for possible third factors. But the correlations suggest that there can be a relationship between the term spread and real economic activity and this connection seems to be stronger in the second subsample.

OLS regressions

In the first subsample, the estimated model including only the domestic term spread perform poorly compared to when the US term spread and oil investments are included. In the second subsample, the performance of the domestic term spread alone improves and is significant different from zero at 1% level. The model which include oil investments, US and German term spreads, provide a higher adjusted r-squared, but the effects of the estimated coefficients upon annual quarterly Norwegian GDP growth are ambiguous. This is because of co-linearity among the term spreads. The first subsample contains country specific factors that affect the estimates of the entire sample, because these are time-varying. The results can be taken in support of the alternative hypothesis, but the country specific factors suggest that the relationship between the term spread and the real economy vary over time. It seems to be very useful to control for international term spreads and oil investments.

The Estrella & Hardouvelis OLS regressions

The results are consistent with the estimates of Estrella & Hardouvelis (1991). The general pattern is consistent, but our estimates are a little weaker. Compared to Isachsen et al. (1998) we obtain similar estimates, even though our sample is larger. These findings suggest rejecting the null hypothesis, even though the results are weaker.

The probit models

The estimates are in general in alignment to theory, and produce recession probabilities that are plausible. The first part of the sample is characterized by consistently high probabilities of recession, and small range between peak and through. The last part of the sample is characterized by more distinct peaks and generally low recession probabilities. The two peaks that are not followed by a recession are plausible in retrospect. This suggests that the out-of-sample forecasts are to some degree unreliable. The probit models that rely on both the domestic and foreign term spread doesn’t provide any additional peaks, but supplement the already estimated peaks by the domestic term spread alone. The probit models that rely on domestic term spread and oil investments does provide additional peaks (but smaller), and suggest that there is additional information outside of the peaks predicted by the domestic term spread. However, the oil investments do not provide supplementary information regarding the already predicted peaks. Overall, these findings support the alternative hypothesis, given valid assumptions.

Out-of-sample forecasting

The probit models seem to predict the recession dated 2001 quarter two and three better than the recession dated 2002 quarter four and 2003 quarter one. The out-of-sample forecasting ability resembles the in-sample performance. This supports the alternative hypothesis, but given the 'false' signals observed in the in-sample predictions, supplementing with additional information should be considered.

The out-of-sample predictions using the standard OLS models produce less volatile predictions which on average under-predicts the real economic development. The prediction does not deviate much from the actual GDP growth in the part of the sample when the actual GDP growth exhibit low volatility. Comparing the results of the out-of-sample forecasting of the standard OLS model to the probit forecast, the findings suggest that the term spread may be a better predictor of extreme than 'normal' developments in real economic development.

These findings could easily be accepted in support for our null and alternative hypothesis, both yes and no. In this respect it's important to notice what is particular about the Norwegian real economy that can influence the conclusion.

We have seen that controlling for oil investments lagged eight quarters improve the relationship between the domestic term spread and real economic activity. It is plausible to believe that the oil sector can be a third factor behind the correlations we observed, given its relative importance in Norway. In this respect it is possible that the information content in the Norwegian term structure can differ from the empirical findings in i.e. the US or the UK. However, it is not clear how the influence of the oil sector should be modeled along with different term spreads. Perhaps a more sophisticated representation in our model could better describe the different effects of the oil sector over different horizons. Underlining the oil sectors importance, is the additional predicted probability peak when the oil investments are included in the probit model.

Another interesting finding in this study is the influence of the international term spreads. Some of the unresolved problems of the structural models is the co-linearity between the domestic and foreign term spreads, causing the estimated coefficients to predict partial effects upon real economic activity that are opposite of what should be expected from theory. However, there is no doubt that the international term spreads should be controlled for. The higher correlations (and more consistent with theory) between foreign term spreads than foreign GDPs and annual quarterly Norwegian GDP growth illustrate this. Country specific factors are time varying and this influence the relationship we study. In example, the US term spread proved very useful in explaining Norwegian real economic activity in the first subsample, in which the domestic term spread consisted of little information. In the second subsample they are both important, even though the significance of the domestic term spread is more important. In addition, there is some information in the German term spread in the second subsample. Including international terms spreads even strengthen the recession signals predicted by the domestic term spread alone. This finding underlines the small country characteristics influencing Norwegian real economic activity. The Norwegian interest rate market is highly correlated with international interest rate markets and long term domestic interest rates cannot deviate from the international term spreads. The ‘false’ recession signals estimated in the probit models is a result of highly correlated interest rate markets; high correlations which strengthens both ‘false’ and ‘true’ recession signals. In this respect, it is valid to expect relatively lower information content in the domestic term spread, compared to countries like US, UK and Germany.

The shifts in the focus of the monetary policy occurring in our sample are also important to consider in a proper assessment of the findings with respect to our hypothesis. The objective of this study wasn’t to study the effect of monetary policy upon the information content of the term spread. Nevertheless, the two are intertwined, and the shift to inflation targeting is included in the second subsample. This is also the period in which the domestic term spreads seems the most informative.

There are also several model specific and econometric issues that are involved in the relationship between the term structure and real economic activity. These could result in a false rejection of the null hypothesis if the OLS conditions are not met. The most concerning conditions in our sample are the ones of stationarity and normality. The statistical tests of both conditions are variable. While it is reasonable to assume the variables to be stationary, the normality assumption is more problematic in the smaller subsamples. In addition, the probit models rely on an appropriate definition of a recession. It seems that our definition is somewhere in between the most scientific and the most 'rule of thumb' oriented definitions. This has the benefit of revealing information in the term structure that is not necessarily associated with a domestic recession. Our definition has the drawback of being a bit inaccurate (according to the discussion on the out-of-sample predictions before the last dated recession).

When we compare the results of the structural regression with the results of the reduced form regression we arrive at an interesting point of view of the relationship in Norway. The results appear to be more consistent for both the in-sample and out-of-sample predictions of the probit models. These are also the predictions with the least structural foundation, and suggest that the term structure can be a better predictor of extreme changes in real economic activity than smaller, continuous changes. The difference between the structural regressions in the two subsamples can also be applied to structural foundation to some degree. The domestic term structure is more informative in the last subsample according to the OLS estimations. The shift to inflation targeting experienced in this period, reduce the structural foundation of the term structure. According to Estrella (2005a) the information content in the yield curve can be reduced to a function of the monetary policy rule. Together these findings suggest that the information in the Norwegian term spread is not theoretically founded.

10. Conclusion

Considering the time varying country specific factors together with several econometric and model specific issues, an unanimous rejection of the null hypothesis is misleading. Nevertheless, it is reasonable to reject the null hypothesis. All of our models imply that there is some information in the term structure regarding the Norwegian real economic activity, even after controlling for international term spreads and the oil sectors influence in a simple manner. It is plausible to reject the null hypothesis with a few remarks regarding the information content:

- The information content in the term structure is stronger when real economic activity is described by extreme change (recession) than continuous change. There is nothing in the theory that explains this. The reason why we observe this could in fact be that the theory consists of a series of loose connections that are based on various empirical findings.
- The information is persistent after controlling for the influence of the oil sector and foreign term spreads.
- Monetary policy seems to play an important role in general. This is also true for the domestic relationship in Norway.
- The information content of the Norwegian term spread regarding the real economic activity seem to be less evident (that is the estimated coefficients are smaller in value) compared to studies conducted on the relationship in the US.

Since we reject the null hypothesis with a few reservations it is necessary to state that the term spread has limited practical value as a leading indicator for the Norwegian real economy according to our models. Both out-of-sample exercises we conducted produced forecasts that were inaccurate and/or produce false signals. This makes the model a bit unreliable. In-sample explanatory power is impressive, but should be supplemented with additional information from other leading indicators for practical purposes i.e. within monetary policy. Perhaps the term spread proves even more informative in such a context. This is the reason we suggest further studies on the relationship between monetary policy's influences over the information value of the term structure.

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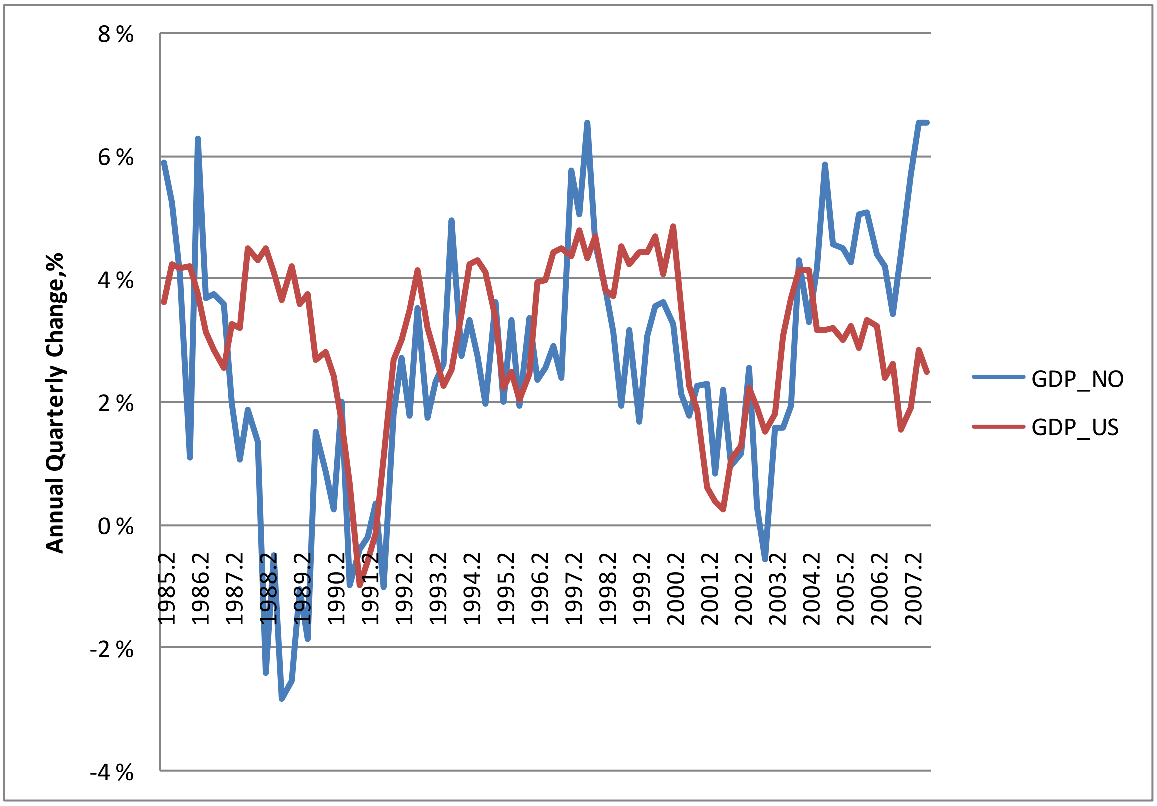
12. Appendix

Appendix 12.1 Correlations

TABLE 12.1: CORRELATIONS BETWEEN ANNUAL QUARTERLY NORWEGIAN GDP GROWTH AND ANNUAL QUARTERLY OIL PRICE GROWTH

Time-period # of lags	1985 - 1996	1997 - 2007	1985 – 2007
0 quarter	-0.19	0.0880	0.08
1 quarters	-0.27	0.0755	0.06
2 quarters	-0.27	0.0829	0.09
3 quarters	-0.09	0.0540	0.12
4 quarters	-0.25	0.1205	0.12
5 quarters	-0.27	0.1310	0.11
6 quarters	-0.20	0.0512	0.07
7 quarters	-0.44	0.0174	-0.04
8 quarters	-0.36	-0.0336	-0.04
9 quarters	-0.03	-0.0788	0.04
10 quarters	0.18	-0.0824	0.11
11 quarters	0.34	-0.0970	0.15
12 quarters	0.49	-0.1684	0.16

FIGURE 12.1: THE US GDP AND NORWEGIAN GDP

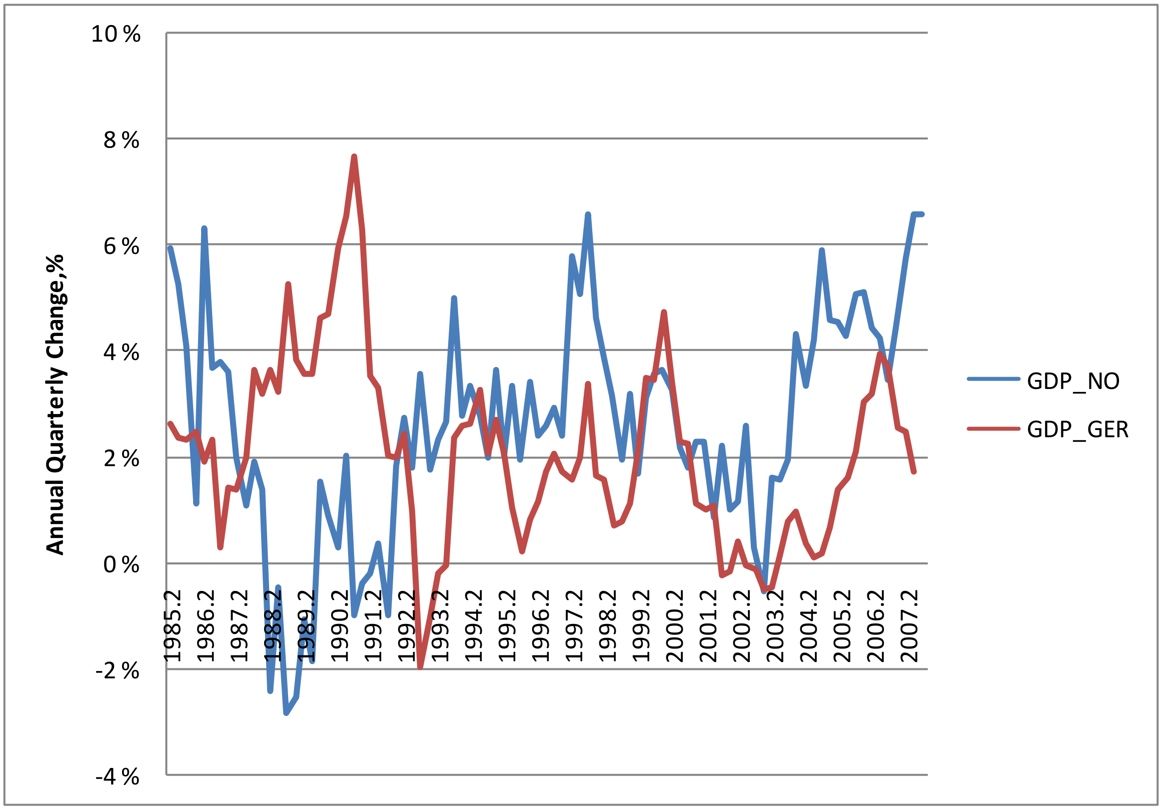


Source: Authors own calculations.

TABLE 12.2: CORRELATIONS BETWEEN NORWEGIAN GDP AND DIFFERENT LAGS OF US GDP

Time-period # of quarters lagged US GDP	1985 – 1996 (47 obs.)	1997 – 2007 (44 obs.)	1985 – 2007 (91 obs.)
0 quarter	0,21	0,37	0,26
1 quarters	0,20	0,37	0,26
2 quarters	0,17	0,33	0,23
3 quarters	0,22	0,33	0,25
4 quarters	0,21	0,34	0,23
5 quarters	0,23	0,23	0,18
6 quarters	0,25	0,16	0,16
7 quarters	0,21	-0,02	0,07
8 quarters	0,15	-0,14	0
9 quarters	0,04	-0,22	-0,08
10 quarters	-0,11	-0,36	-0,20
11 quarters	-0,26	-0,39	-0,28
12 quarters	-0,34	-0,38	-0,31

FIGURE 12.2: THE GERMAN GDP AND NORWEGIAN GDP



Source: Authors own calculations.

TABLE 12.3: CORRELATIONS BETWEEN NORWEGIAN GDP AND GERMAN GDP

Time-period # of quarters lagged German GDP	1985 – 1996 (47 obs.)	1997 – 2007 (44 obs.)	1985 – 2007 (91 obs.)
0 quarter	-0,48	0,38	-0,27
1 quarters	-0,48	0,31	-0,30
2 quarters	-0,47	0,23	-0,32
3 quarters	-0,39	0,16	-0,30
4 quarters	-0,22	0,02	-0,26
5 quarters	-0,14	-0,21	-0,29
6 quarters	-0,02	-0,27	-0,25
7 quarters	0,05	-0,41	-0,24
8 quarters	-0,05	-0,43	-0,30
9 quarters	-0,07	-0,44	-0,30
10 quarters	-0,05	-0,51	-0,30
11 quarters	-0,13	-0,51	-0,33
12 quarters	-0,11	-0,40	-0,28

TABLE 12.4: CORRELATIONS BETWEEN NORWEGIAN GDP AND GERMAN TERM SPREAD

Time-period # of quarters lagged German term spread	1985 – 1996 (47 obs.)	1997 – 2007 (42 obs.)	1985 – 2007 (89 obs.)
0 quarter	0,28	-0,04	0,21
1 quarters	0,13	0,16	0,18
2 quarters	0,03	0,31	0,17
3 quarters	-0,05	0,40	0,16
4 quarters	-0,12	0,45	0,15
5 quarters	-0,18	0,48	0,13
6 quarters	-0,19	0,49	0,15
7 quarters	-0,19	0,51	0,16
8 quarters	-0,19	0,47	0,15
9 quarters	-0,18	0,43	0,15
10 quarters	-0,28	0,36	0,07
11 quarters	-0,39	0,27	-0,01
12 quarters	-0,47	0,18	-0,08

TABLE 12.5: CORRELATIONS BETWEEN GERMAN GDP AND US TERM SPREAD

Time-period # of quarters lagged US spread	1985 – 1996 (47 obs.)	1997 – 2007 (44 obs.)	1985 – 2007 (91 obs.)
0 quarter	-0,32	-0,78	-0,38
1 quarters	-0,38	-0,72	-0,38
2 quarters	-0,43	-0,63	-0,37
3 quarters	-0,48	-0,57	-0,38
4 quarters	-0,52	-0,52	-0,38
5 quarters	-0,55	-0,44	-0,35
6 quarters	-0,55	-0,34	-0,32
7 quarters	-0,51	-0,21	-0,24
8 quarters	-0,39	-0,07	-0,13
9 quarters	-0,19	0,07	0,02
10 quarters	0,02	0,22	0,18
11 quarters	0,17	0,32	0,29
12 quarters	0,22	0,41	0,34

TABLE 12.6: CORRELATIONS BETWEEN US GDP AND US TERM SPREAD

Time-period # of quarters lagged US Spread	1985 – 1996 (47 obs.)	1997 – 2007 (44 obs.)	1985 – 2007 (91 obs.)
0 quarter	0,11	-0,23	-0,07
1 quarters	0,26	-0,08	0,08
2 quarters	0,37	0,05	0,19
3 quarters	0,41	0,12	0,25
4 quarters	0,43	0,14	0,27
5 quarters	0,49	0,15	0,30
6 quarters	0,53	0,15	0,32
7 quarters	0,57	0,15	0,33
8 quarters	0,52	0,18	0,33
9 quarters	0,42	0,21	0,30
10 quarters	0,26	0,23	0,23
11 quarters	0,11	0,21	0,15
12 quarters	-0,02	0,19	0,08

TABLE 12.7: CORRELATIONS BETWEEN GERMAN GDP AND GERMAN TERM SPREAD

Time-period # of lagged German term spread	1985 – 1996 (47 obs.)	1997 – 2007 (42 obs.)	1985 – 2007 (89 obs.)
0 quarter	-0,29	-0,49	-0,35
1 quarters	-0,17	-0,30	-0,23
2 quarters	-0,07	-0,13	-0,14
3 quarters	0,02	-0,02	-0,06
4 quarters	0,08	0,02	-0,03
5 quarters	0,10	0,04	-0,02
6 quarters	0,12	0,08	-0,01
7 quarters	0,20	0,14	0,05
8 quarters	0,29	0,22	0,12
9 quarters	0,37	0,32	0,20
10 quarters	0,45	0,42	0,26
11 quarters	0,50	0,48	0,30
12 quarters	0,56	0,52	0,35

Appendix 12.2 Newey-West correction of standard errors

TABLE 12.8: AUTOCORRELATION TESTS FOR LAGS >K-1

Variable	K-1	First lag that reject H0 for lags>K-1	Chi squared	P-value	Number of lags to be corrected
ck1	0	28	40.260	0.0627	27
ck2	1	35	48.816	0.0605	34
ck3	2	48	64.720	0.0540	47
ck4	3	50	67.181	0.0528	49
ck5	4	49	65.817	0.0546	48
ck6	5	53	70.665	0.0528	52
ck7	6	57	75.018	0.0551	56
ck8	7	52	69.555	0.0524	51
ck12	11	52	69.700	0.0511	51
ck16	15	52	69.340	0.0542	51
ck20	19	49	66.342	0.005	48
mk1	0	28	40.260	0.0627	27
mk2	1	17	27.351	0.0531	16
mk3	2	20	31.410	0.0500	19
mk4	3	16	25.850	0.0562	15
mk5	4	17	27.173	0.0556	16
mk6	5	20	30.498	0.0622	19
mk7	6	21	32.251	0.0552	20
mk8	7	22	33.652	0.0533	21
mk12	11	45	61.164	0.0545	44
mk16	15	41	56.288	0.0563	40
mk20	19	42	57.247	0.0585	41

Appendix 12.3 Tests for stationarity

TABLE 12.9: ADF-TESTS FOR UNIT ROOT

Variable	Trend	Constant	Coefficient	t-value	Mackinnon approximate p-value at 5% level[1]	Conclusion
GDP_NO						
No constant			-0.0894	-2.035	0.0044	Reject H0
Drift		0.0062	-0.2428	-3.680	0.0002	Reject H0
Trend	0.0001	0.0025	-0.2958	-4.227	0.0041	Reject H0
SPREAD_NO						
No constant			-0.0740	-1.848	0.0680	Dont reject
Drift		0.0004	-0.0824	-1.938	0.3146	Dont reject
Trend	0.0000	-0.0001	-0.0915	-1.952	0.6275	Dont reject
SPREAD_US						
No constant			-0.0654	-1.990	0.0490	Reject
Drift		0.0029	-0.1734	-3.587	0.0003	Reject
Trend	0.0000	0.0041	-0.1737	-3.593	0.0304	Reject
SPREAD_GER						
No constant			-0.0329	-1.346	0.1810	Dont reject
Drift		0.0007	-0.0614	-1.885	0.0311	Reject
Trend		0.0000	0.0010	-0.058	0.7547	Dont reject
OILINV						
No constant			-0.5874	-6.627	0.000	Reject
Drift		0.0375	-0.6247	-6.912	0.0000	Reject
Trend	-0.0003	0.0545	-0.6273	-6.901	0.0000	Reject
GDP_US						
No constant			-0.0388	-1.447	0.1510	Dont reject
Drift		0.0041	-0.1362	-2.851	0.0026	Reject
Trend	0.0000	0.0044	-0.1358	-2.823	0.1885	Dont reject
GDP_GER						
No constant			-0.0763	-2.022	0.0460	Reject
Drift		0.0038	-0.1852	-3.333	0.0006	Reject
Trend	-0.0000	0.0051	-0.1892	-3.380	0.0542	Dont reject

[1]For the no constant models the regular p-values are reported. These are approximately equal to the Mackinnon approximate p-value in a model without constant in the regression.

Appendix 12.4 Tests for normality

TABLE 12.10: NORMALITY TESTS FOR THE ENTIRE SAMPLE

Variable	Pr(Skewness)	Pr(Kurtosis)	Adjusted chi-sqared	Pr>Chi-squared	Conclusion
Spread 10yr-3mnth	0.257	0.003	8.88	0.0118	Reject
Spread 10yr-6mnth	0.103	0.001	12.12	0.0023	Reject
Spread 10yr-9mnth	0.058	0.000	13.29	0.0013	Reject
Spread 10yr-1yr	0.052	0.001	12.50	0.0019	Reject
Spread 5yr-3mnd	0.527	0.195	2.14	0.3439	Don't Reject
Spread 5yr-6mnth	0.183	0.035	5.91	0.0522	Don't Reject
Spread 5yr-9mnth	0.092	0.009	8.54	0.0140	Reject
Spread 5yr-1yr	0.103	0.009	8.37	0.0152	Reject
Spread 3yr-3mnth	0.253	0.462	1.90	0.3862	Don't Reject
Spread 3yr-6mnth	0.796	0.868	0.009	0.9538	Don't Reject
Spread 3yr-9mnth	0.908	0.215	1.60	0.4504	Don't Reject
Spread 3yr-1yr	0.716	0.124	2.58	0.2754	Don't Reject
GDP_NO	0.504	0.965	0.45	0.7971	Don't Reject
Oilprice annual growth	0.001	0.011	13.98	0.0009	Reject
Oil investments annual growth	0.018	0.217	6.60	0.0369	Reject
Spread_US	0.020	0.962	5.31	0.0704	Don't Reject
GDP_US	0.096	0.024	7.21	0.0272	Reject
Spread_GER	0.026	0.898	4.95	0.0840	Don't Reject
GDP_GER	0.023	0.174	6.57	0.0374	Reject

TABLE 12.11: NORMALITY TESTS FOR THE FIRST SUBSAMPLE

Variable	Pr(Skewness)	Pr(Kurtosis)	Adjusted chi-squared	Pr>Chi-squared	Conclusion
Spread 10yr-3mnth	0.032	0.505	4.95	0.0841	Don't Reject
Spread 10yr-6mnth	0.031	0.264	5.62	0.0601	Don't Reject
Spread 10yr-9mnth	0.031	0.178	6.04	0.0488	Reject
Spread 10yr-1yr	0.033	0.163	6.07	0.0481	Reject
Spread 5yr-3mnd	0.018	0.557	5.65	0.0593	Don't Reject
Spread 5yr-6mnth	0.017	0.962	5.49	0.0641	Don't Reject
Spread 5yr-9mnth	0.018	0.729	5.51	0.0637	Don't Reject
Spread 5yr-1yr	0.021	0.585	5.39	0.0674	Don't Reject
Spread 3yr-3mnth	0.028	0.317	5.55	0.0624	Don't Reject
Spread 3yr-6mnth	0.027	0.583	5.10	0.0779	Don't Reject
Spread 3yr-9mnth	0.040	0.765	4.42	0.1099	Don't Reject
Spread 3yr-1yr	0.085	0.962	3.19	0.2027	Don't Reject
GDP_NO	0.357	0.940	0.89	0.6422	Don't Reject
Oilprice annual growth	0.538	0.766	0.48	0.7869	Don't Reject
Oil investments annual growth	0.057	0.292	4.72	0.0943	Don't Reject
Spread_US	0.509	0.011	6.33	0.0422	Reject
GDP_US	0.000	0.033	13.37	0.0013	Reject
Spread_GER	0.735	0.000	10.65	0.0049	Reject
GDP_GER	0.361	0.245	2.31	0.3146	Don't Reject

TABLE 12.12: NORMALITY TESTS FOR THE SECOND SUBSAMPLE

Variable	Pr(Skewness)	Pr(Kurtosis)	Adjusted chi-squared	Pr>Chi-squared	Conclusion
Spread 10yr-3mnth	0.613	0.174	2.23	0.3278	Don't Reject
Spread 10yr-6mnth	0.817	0.017	5.48	0.0645	Don't Reject
Spread 10yr-9mnth	0.499	0.003	7.86	0.0196	Reject
Spread 10yr-1yr	0.383	0.002	8.51	0.0142	Reject
Spread 5yr-3mnd	0.181	0.774	1.99	0.3704	Don't Reject
Spread 5yr-6mnth	0.758	0.083	3.31	0.1907	Don't Reject
Spread 5yr-9mnth	0.701	0.005	7.23	0.0269	Reject
Spread 5yr-1yr	0.503	0.002	8.66	0.0131	Reject
Spread 3yr-3mnth	0.013	0.300	6.57	0.0374	Reject
Spread 3yr-6mnth	0.222	0.544	1.97	0.3732	Don't Reject
Spread 3yr-9mnth	0.883	0.009	6.32	0.0425	Reject
Spread 3yr-1yr	0.813	0.001	9.18	0.0102	Reject
GDP_NO	0.966	0.484	0.50	0.7775	Don't Reject
Oilprice annual growth	0.008	0.058	9.06	0.0108	Reject
Oil investments annual growth	0.033	0.007	9.80	0.0074	Reject
Spread_US	0.211	0.010	7.26	0.0266	Reject
GDP_US	0.166	0.270	3.35	0.1875	Don't Reject
Spread_GER	0.892	0.430	0.66	0.7172	Don't Reject
GDP_GER	0.264	0.324	2.36	0.3075	Don't Reject

Appendix 12.5 Probit models with different recession definitions

TABLE 12.13: PSEUDO R-SQUARED AND Z-STATISTICS FOR PROBIT MODELS USING NORWEGIAN TERM SPREAD, 'STRONG- AND MINIRECESSION'

	Number of quarters (k) ahead						
	0	2	4	6	8	10	12
'Strongrecession' in quarter k							
Pseudo – R^2	0.0377	0.0848	0.1352	0.1223	0.1384	0.0851	0.0621
Norwegian spread	-0.24(0.17)	-0.38(0.19)	-0.51(0.22)	-0.48(0.21)	-0.53(0.23)	-0.38(0.20)	-0.32(0.19)
Z – value	-1.41 (0.158)	-1.98 (0.047)**	-2.30 (0.021)**	-2.23 (0.026)**	-2.27 (0.023)**	-1.93 (0.054)*	-1.69 (0.091)*
Constant	-1.23(0.18)	-1.25(0.19)	-1.29(0.18)	-1.27(0.21)	-1.29(0.23)	-1.22(0.20)	-1.20(0.20)
Z – value	-6.69 (0.000)***	-6.41 (0.000)***	-5.95 (0.000)***	-5.99 (0.000)***	-5.73 (0.000)***	-6.05 (0.000)***	-6.09 (0.000)***
Log likelihood	-28.15	-26.58	-24.93	-25.11	-24.45	-25.94	-26.16
'Minirecession' in quarter k							
Pseudo – R^2	0.0254	0.0431	0.0398	0.0490	0.0580	0.0808	0.0258
Norwegian spread	-0.19(0.12)	-0.25(0.12)	-0.23(0.12)	-0.25(0.12)	-0.29(0.13)	-0.35(0.14)	-0.19(0.13)
Z – value	-1.59 (0.12)	-2.01 (0.044)**	-1.93 (0.053)*	-2.09 (0.037)**	-2.24 (0.025)**	-2.52 (0.012)**	-1.47 (0.142)
Constant	-0.59(0.15)	-0.60(0.15)	-0.59(0.15)	-0.61(0.15)	-0.59(0.15)	-0.62(0.16)	-0.66(0.16)
Z – value	-4.01 (0.000)***	-4.01 (0.000)***	-3.88 (0.000)***	-3.94 (0.000)***	-3.85 (0.000)***	-3.89 (0.000)***	-4.17 (0.000)***
Log likelihood	-49.85	-47.35	-46.96	-44.92	-43.95	-41.10	-42.19

Z-statistics; *, ** and *** denote significance at the 10%, 5% and 1% level respectively. The estimated coefficients are reported together with the standard errors in parenthesis. The p-value of the coefficients is reported in parenthesis behind z-value.

Appendix 12.6 Probit models with foreign term spreads only

TABLE 12.14: PSEUDO R-SQUARED AND T-STATISTICS FOR PROBIT MODELS USING GERMAN TERM SPREAD, RECESSION IN AND WITHIN QUARTER K.

	Number of quarters (k) ahead						
	0	2	4	6	8	10	12
Recession in quarter k							
Pseudo – R^2	0.0419	0.0886	0.1085	0.0179	0.0002	0.0049	0.0251
German spread	-0.22(0.12)	-0.33(0.13)	-0.37(0.13)	-0.15(0.13)	-0.01(0.13)	0.08(0.15)	0.20(0.17)
Z – value	-1.80 (0.072)*	-2.58 (0.010)***	-2.79 (0.005)***	-1.16 (0.247)	-0.11 (0.911)	0.54 (0.589)	1.12 (0.261)
Constant	-0.99 (0.19)	-0.91(0.18)	-0.87(0.19)	-1.06(0.20)	-1.23(0.22)	-1.44(0.26)	-1.66(0.31)
Z – value	-5.29 (0.000)***	-4.97 (0.000)***	-4.68 (0.000)***	-5.29 (0.000)***	-5.60 (0.000)***	-5.61 (0.000)***	-5.27 (0.000)***
Log likelihood	-38.29	-36.30	-35.28	-36.65	-34.99	-30.20	-27.10
Recession within quarter k							
Pseudo – R^2		0.0869	0.0840	0.0651	0.0371	0.0297	0.0258
German Spread		-0.33(0.12)	-0.35(0.11)	-0.31(0.11)	-0.23(0.10)	-0.21(0.10)	-0.19(0.10)
Z – value		-2.87 (0.004)***	-3.15 (0.002)***	-2.91 (0.004)***	-2.25 (0.025)**	-2.02 (0.044)**	-1.86 (0.063)
Constant		- 0.65(0.17)	- 0.28(0.17)	-0.07(0.17)	0.01(0.17)	0.10(0.17)	0.22(0.17)
Z – value		-3.79 (0.000)***	-1.69 (0.090)*	-0.39 (0.698)	0.05 (0.961)	0.62 (0.535)	1.31 (0.190)
Log likelihood		-46.22	-57.55	-64.10	-67.55	-68.12	-66.84

Z-statistics; *, ** and *** denote significance at the 10%, 5% and 1% level respectively. The estimated coefficients are reported together with the standard errors in parenthesis. The p-value of the coefficients is reported in parenthesis behind z-value.

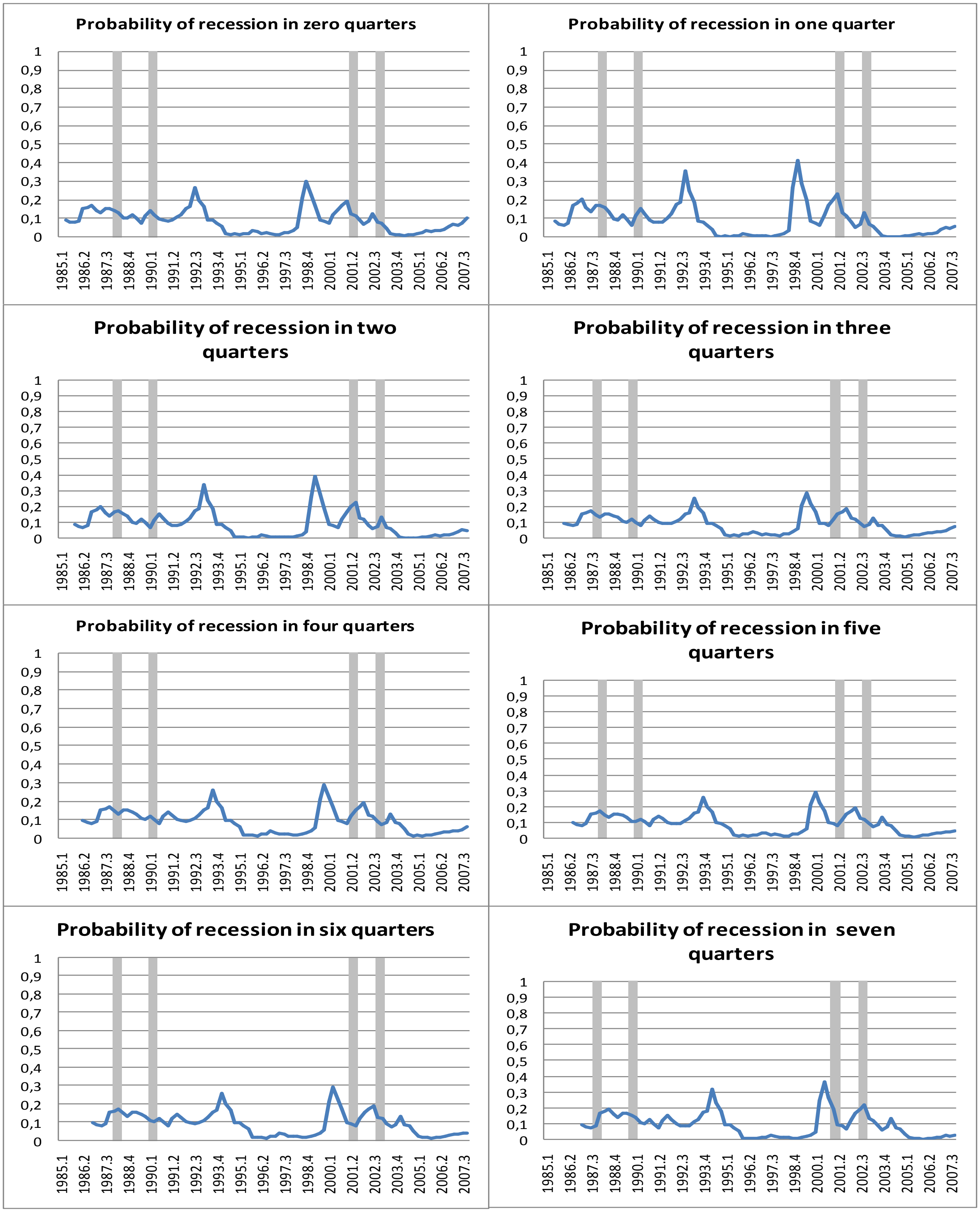
TABLE 12.15: PSEUDO R SQUARED AND T-STATISTICS FOR PROBIT MODELS USING US TERM SPREAD, RECESSION IN AND WITHIN QUARTER K.

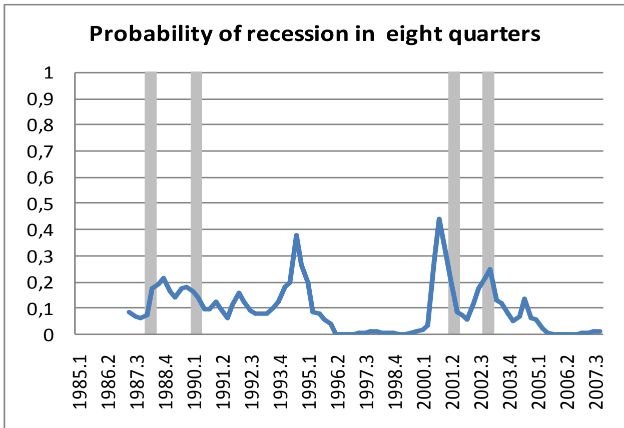
	Number of quarters (k) ahead						
	0	2	4	6	8	10	12
Recession in quarter k							
Pseudo – R^2	0.0419	0.0700	0.1006	0.1125	0.0645	0.0264	0.0004
US spread	-0.07(0.11)	-0.26(0.11)	-0.32(0.12)	-0.36(0.13)	-0.26(0.13)	-0.16(0.12)	-0.02(0.14)
Z – value	-0.62 (0.54)	-2.31 (0.021)**	-2.73 (0.006)***	-2.74 (0.006)***	-2.10 (0.036)**	-1.27 (0.204)	-0.14 (0.889)
Constant	-1.09(0.22)	-0.84(0.21)	-0.75(0.21)	-0.75(0.22)	-0.88(0.23)	-1.11(0.25)	-1.37(0.29)
Z – value	-4.87 (0.000)***	-4.03 (0.000)***	-3.55 (0.000)***	-3.38 (0.001)***	-3.87 (0.000)***	-4.51 (0.000)***	-4.71 (0.000)***
Log likelihood	-39.90	-37.05	-35.60	-33.12	-32.74	-29.55	-27.78
Recession within quarter k							
Pseudo – R^2		0.0665	0.0686	0.1083	0.1737	0.1376	0.1390
US Spread		-0.27(0.11)	-0.29(0.10)	-0.39(0.11)	-0.44(0.11)	-0.47(0.12)	-0.47(0.12)
Z – value		-2.53 (0.011**)	-2.86 (0.004)***	-3.62 (0.000)***	-3.86 (0.000)***	-4.01 (0.000)***	-3.97 (0.000)***
Constant		-0.59(0.20)	-0.20(0.19)	0.21 (0.21)	0.46 (0.23)	0.66 (0.24)	0.83 (0.25)
Z – value		-2.98 (0.003)***	-1.04 (0.300)	1.01 (0.313)	2.02 (0.043)**	2.75 (0.006)***	3.28 (0,001)***
Log likelihood		-47.26	-58.52	-61.14	-61.47	-60.55	-59.08

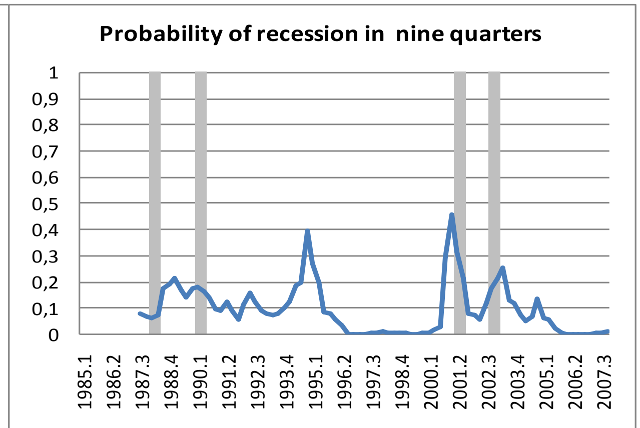
Z-statistics; *, ** and *** denote significance at the 10%, 5% and 1% level respectively. The estimated coefficients are reported together with the standard errors in parenthesis. The p-value of the coefficients is reported in parenthesis behind z-value.

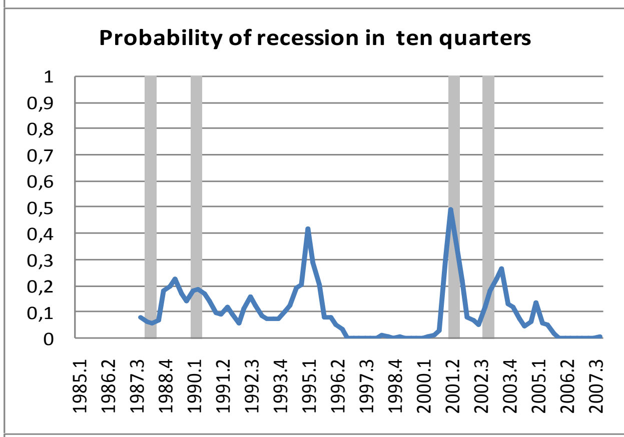
Appendix 12.7 The probability graphs

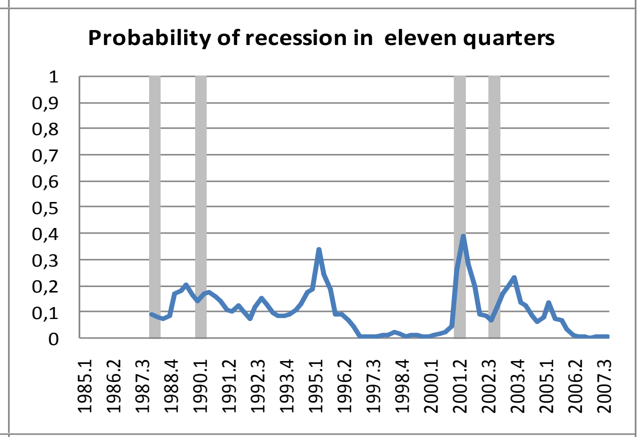
FIGURE 12.3: PROBIT GRAPHS USING THE DOMESTIC TERM SPREAD




Probability of recession in eight quarters
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
1985.1
1986.2
1987.3
1988.4
1990.1
1991.2
1992.3
1993.4
1995.1
1996.2
1997.3
1998.4
2000.1
2001.2
2002.3
2003.4
2005.1
2006.2
2007.3


Probability of recession in nine quarters
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
1985.1
1986.2
1987.3
1988.4
1990.1
1991.2
1992.3
1993.4
1995.1
1996.2
1997.3
1998.4
2000.1
2001.2
2002.3
2003.4
2005.1
2006.2
2007.3


Probability of recession in ten quarters
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
1985.1
1986.2
1987.3
1988.4
1990.1
1991.2
1992.3
1993.4
1995.1
1996.2
1997.3
1998.4
2000.1
2001.2
2002.3
2003.4
2005.1
2006.2
2007.3


Probability of recession in eleven quarters
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
1985.1
1986.2
1987.3
1988.4
1990.1
1991.2
1992.3
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2001.2
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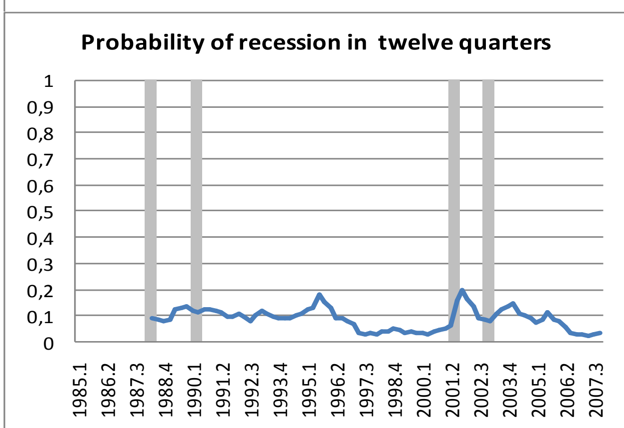
2003.4
2005.1
2006.2
2007.3


Probability of recession in twelve quarters
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
1985.1
1986.2
1987.3
1988.4
1990.1
1991.2
1992.3
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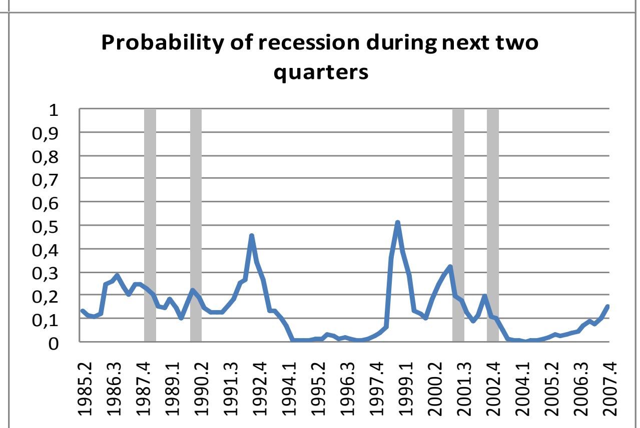
2005.1
2006.2
2007.3


Probability of recession during next two quarters
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
1985.2
1986.3
1987.4
1989.1
1990.2
1991.3
1992.4
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2000.2
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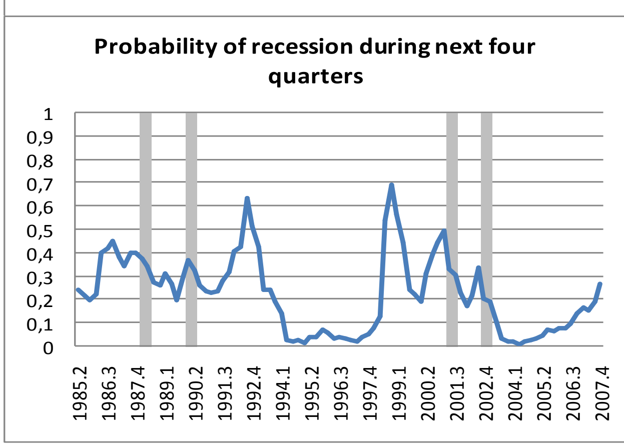
2004.1
2005.2
2006.3
2007.4


Probability of recession during next four quarters
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
1985.2
1986.3
1987.4
1989.1
1990.2
1991.3
1992.4
1994.1
1995.2
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1997.4
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2000.2
2001.3
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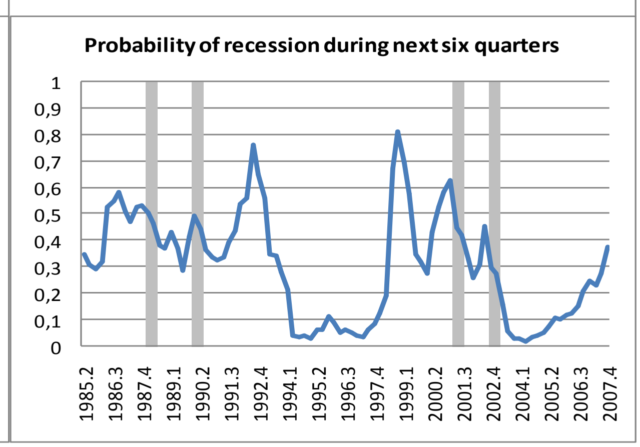
2004.1
2005.2
2006.3
2007.4


Probability of recession during next six quarters
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
1985.2
1986.3
1987.4
1989.1
1990.2
1991.3
1992.4
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1997.4
1999.1
2000.2
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2004.1
2005.2
2006.3
2007.4

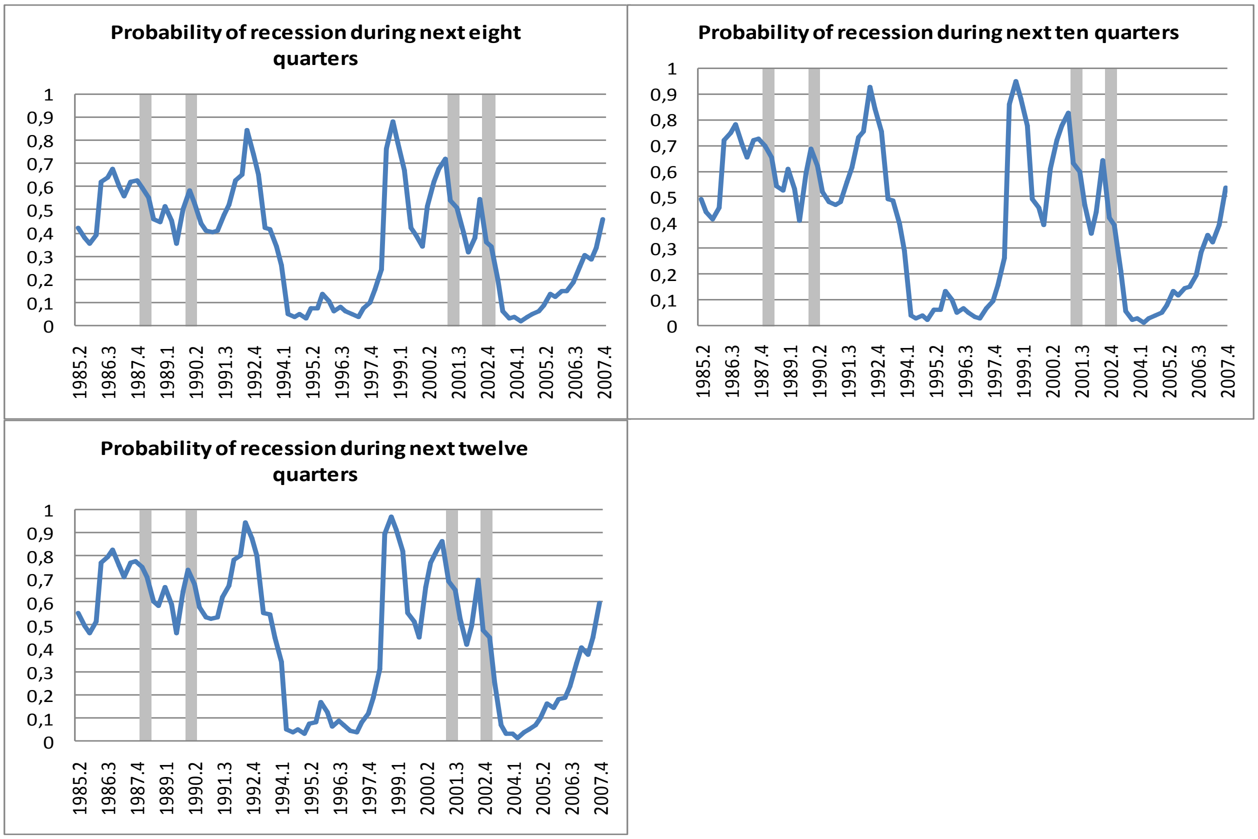
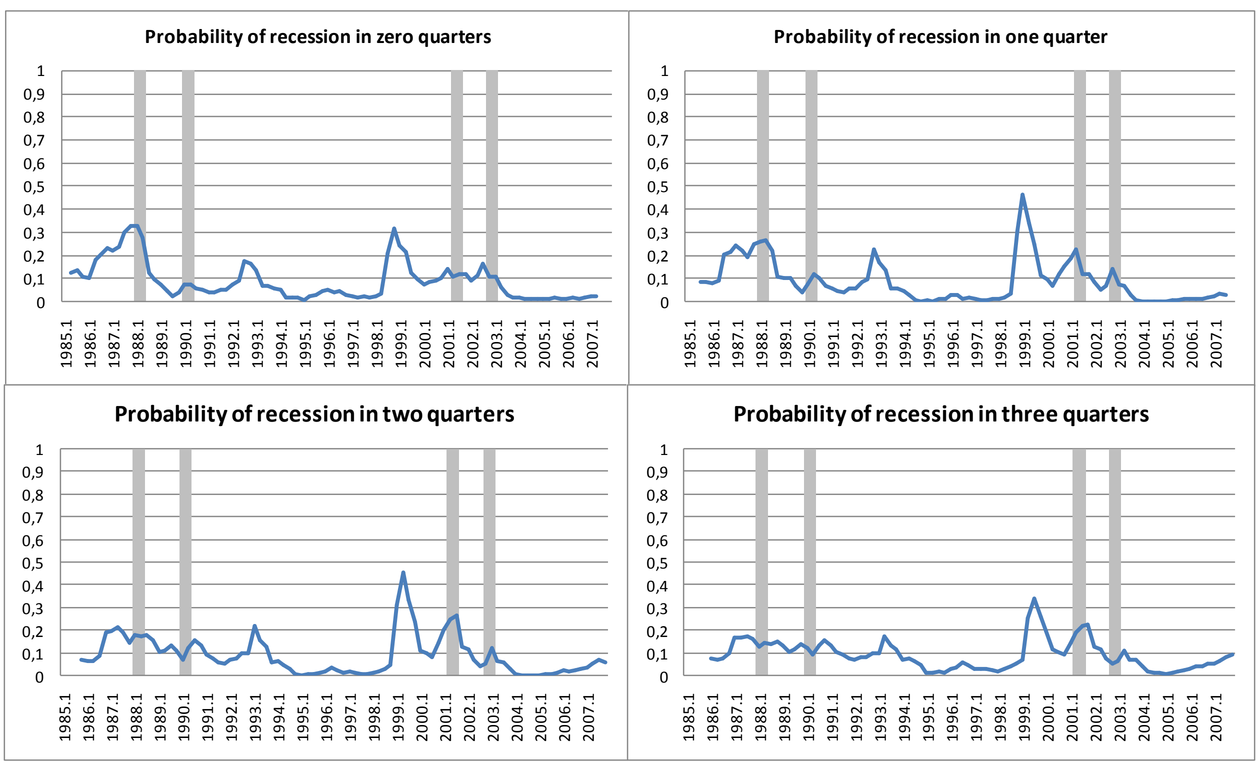
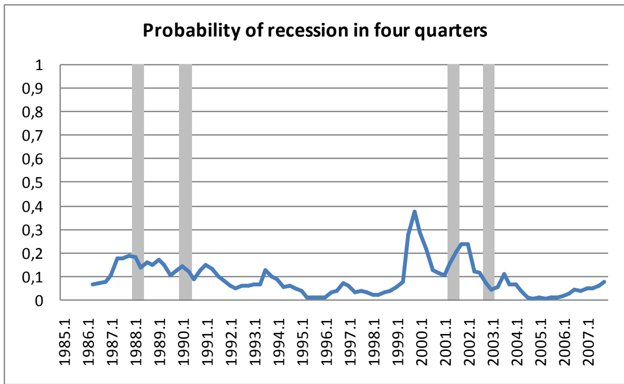
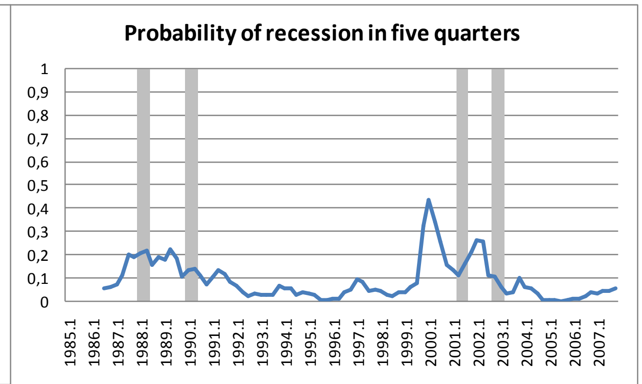
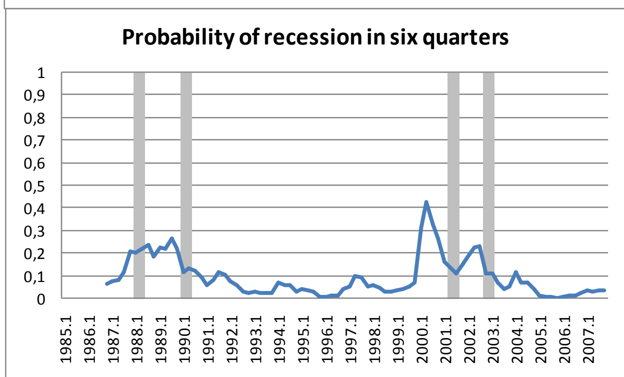


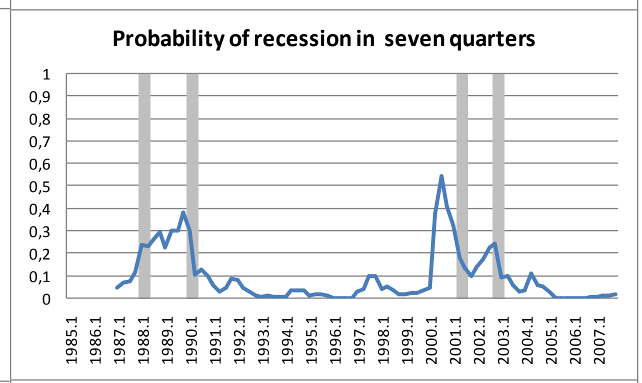
FIGURE 12.4: PROBIT GRAPHS USING THE DOMESTIC TERM SPREAD AND OIL INVESTMENTS

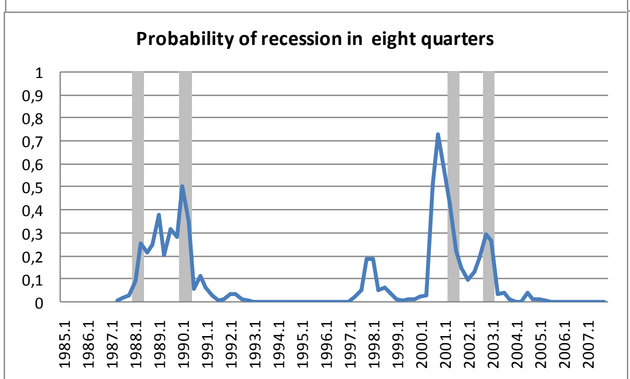


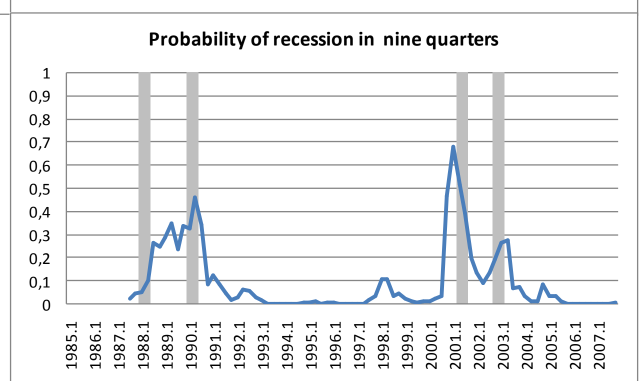

Probability of recession in four quarters
1 0,9 0,8 0,7 0,6 0,5 0,4 0,3 0,2 0,1 0
1985.1 1986.1 1987.1 1988.1 1989.1 1990.1 1991.1 1992.1 1993.1 1994.1 1995.1 1996.1 1997.1 1998.1 1999.1 2000.1 2001.1 2002.1 2003.1 2004.1 2005.1 2006.1 2007.1

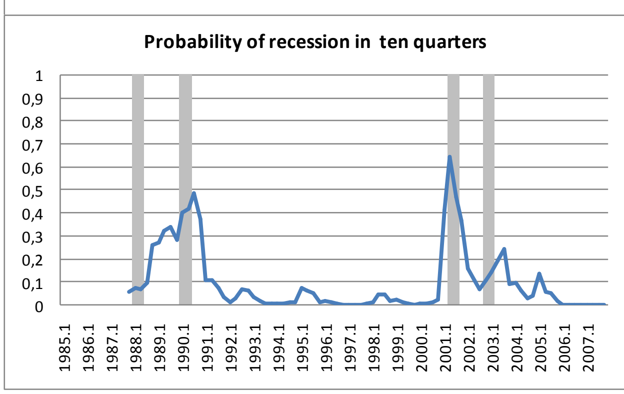

Probability of recession in five quarters
1 0,9 0,8 0,7 0,6 0,5 0,4 0,3 0,2 0,1 0
1985.1 1986.1 1987.1 1988.1 1989.1 1990.1 1991.1 1992.1 1993.1 1994.1 1995.1 1996.1 1997.1 1998.1 1999.1 2000.1 2001.1 2002.1 2003.1 2004.1 2005.1 2006.1 2007.1

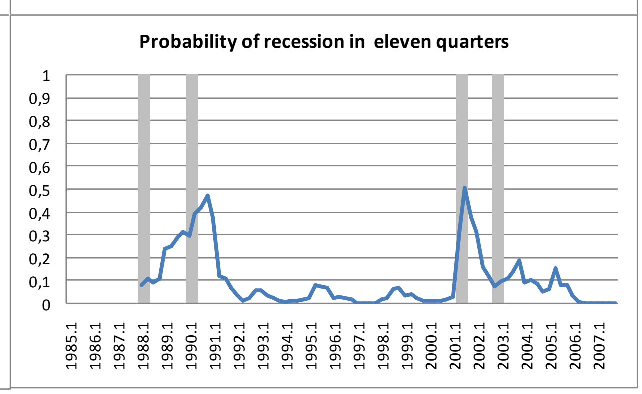

Probability of recession in six quarters
1 0,9 0,8 0,7 0,6 0,5 0,4 0,3 0,2 0,1 0
1985.1 1986.1 1987.1 1988.1 1989.1 1990.1 1991.1 1992.1 1993.1 1994.1 1995.1 1996.1 1997.1 1998.1 1999.1 2000.1 2001.1 2002.1 2003.1 2004.1 2005.1 2006.1 2007.1

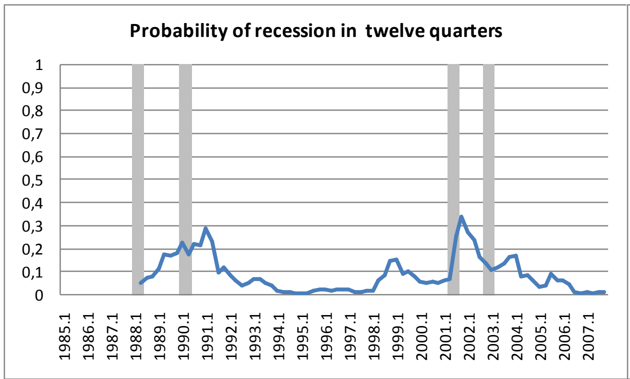

Probability of recession in seven quarters
1 0,9 0,8 0,7 0,6 0,5 0,4 0,3 0,2 0,1 0
1985.1 1986.1 1987.1 1988.1 1989.1 1990.1 1991.1 1992.1 1993.1 1994.1 1995.1 1996.1 1997.1 1998.1 1999.1 2000.1 2001.1 2002.1 2003.1 2004.1 2005.1 2006.1 2007.1

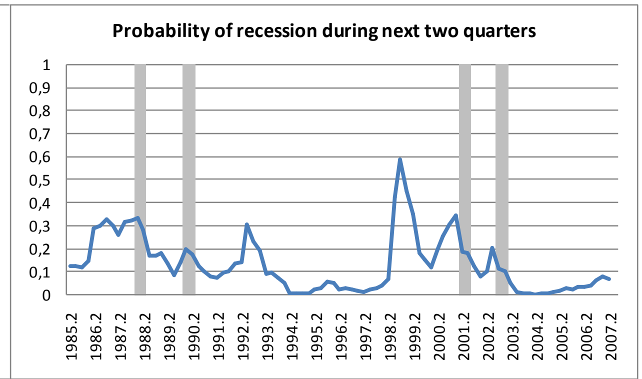

Probability of recession in eight quarters
1 0,9 0,8 0,7 0,6 0,5 0,4 0,3 0,2 0,1 0
1985.1 1986.1 1987.1 1988.1 1989.1 1990.1 1991.1 1992.1 1993.1 1994.1 1995.1 1996.1 1997.1 1998.1 1999.1 2000.1 2001.1 2002.1 2003.1 2004.1 2005.1 2006.1 2007.1

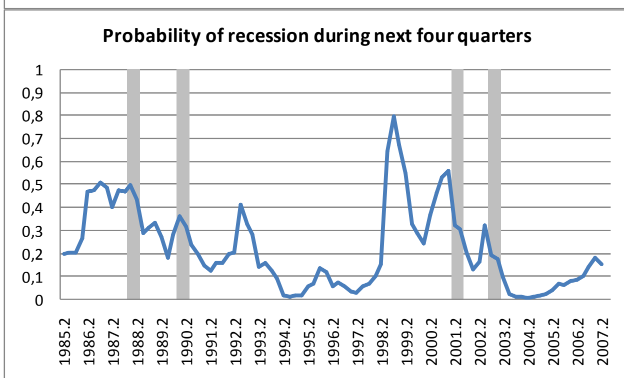

Probability of recession in nine quarters
1 0,9 0,8 0,7 0,6 0,5 0,4 0,3 0,2 0,1 0
1985.1 1986.1 1987.1 1988.1 1989.1 1990.1 1991.1 1992.1 1993.1 1994.1 1995.1 1996.1 1997.1 1998.1 1999.1 2000.1 2001.1 2002.1 2003.1 2004.1 2005.1 2006.1 2007.1

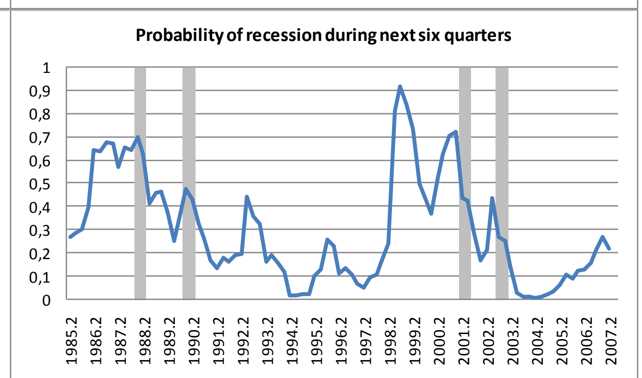

Probability of recession in ten quarters
1 0,9 0,8 0,7 0,6 0,5 0,4 0,3 0,2 0,1 0
1985.1 1986.1 1987.1 1988.1 1989.1 1990.1 1991.1 1992.1 1993.1 1994.1 1995.1 1996.1 1997.1 1998.1 1999.1 2000.1 2001.1 2002.1 2003.1 2004.1 2005.1 2006.1 2007.1

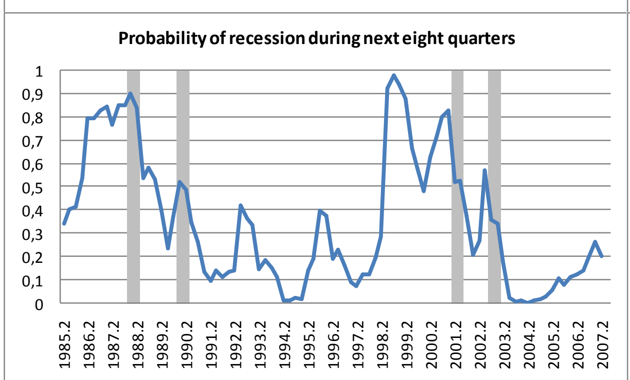

Probability of recession in eleven quarters
1 0,9 0,8 0,7 0,6 0,5 0,4 0,3 0,2 0,1 0
1985.1 1986.1 1987.1 1988.1 1989.1 1990.1 1991.1 1992.1 1993.1 1994.1 1995.1 1996.1 1997.1 1998.1 1999.1 2000.1 2001.1 2002.1 2003.1 2004.1 2005.1 2006.1 2007.1

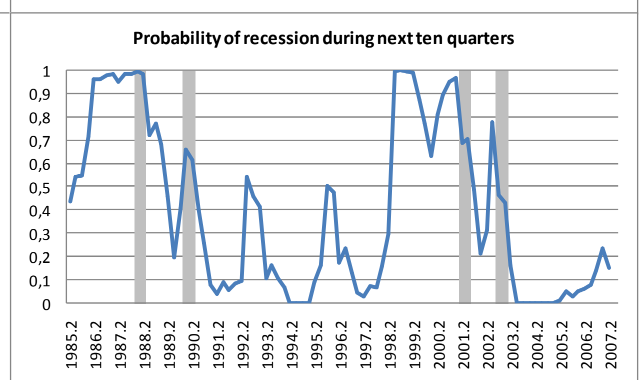

Probability of recession in twelve quarters


Probability of recession during next two quarters


Probability of recession during next four quarters


Probability of recession during next six quarters


Probability of recession during next eight quarters


Probability of recession during next ten quarters

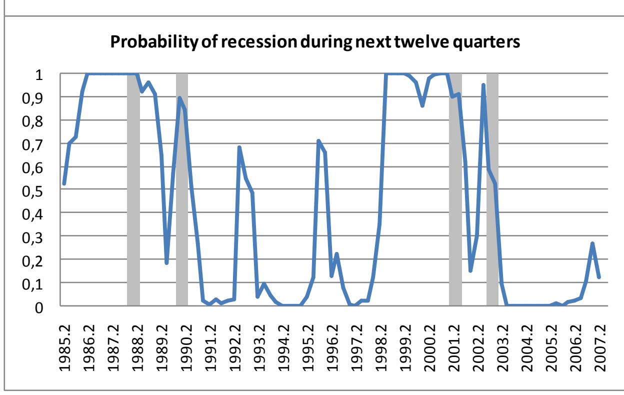
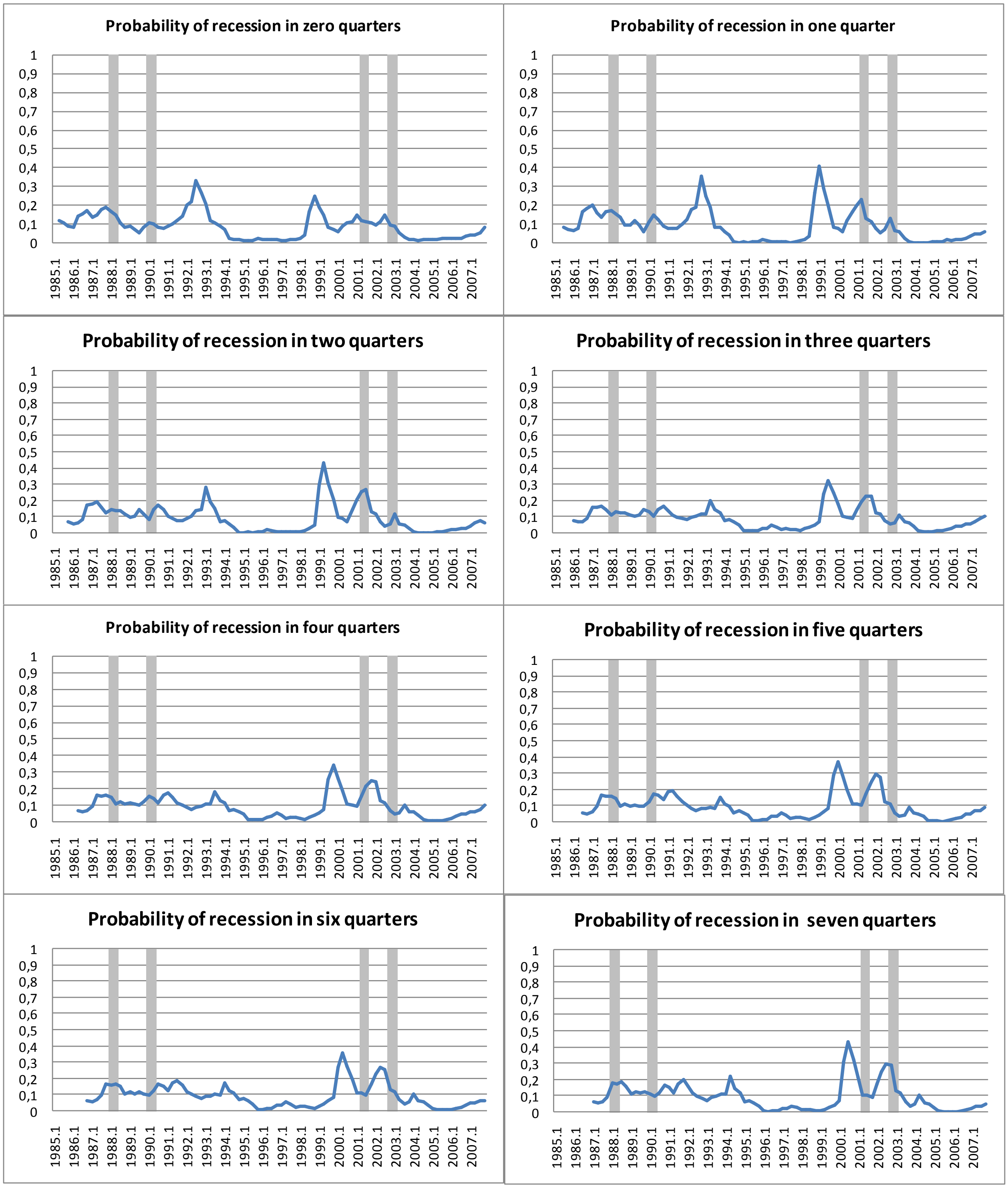
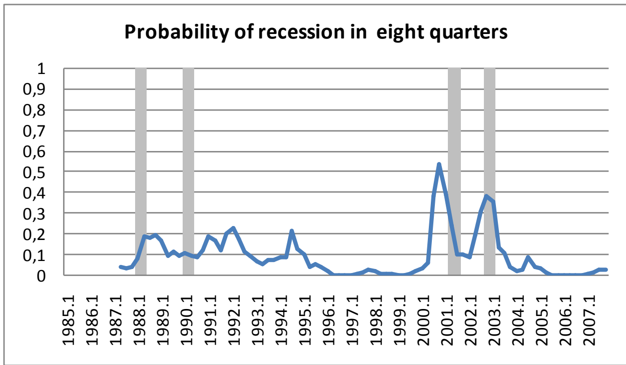
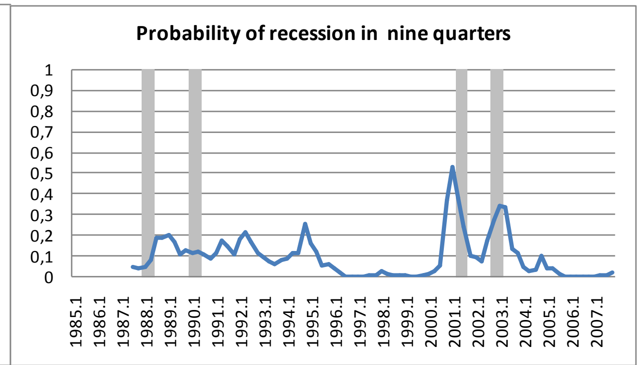
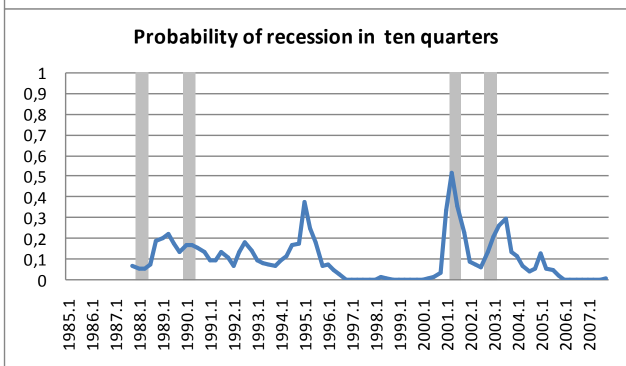

Probability of recession during next twelve quarters

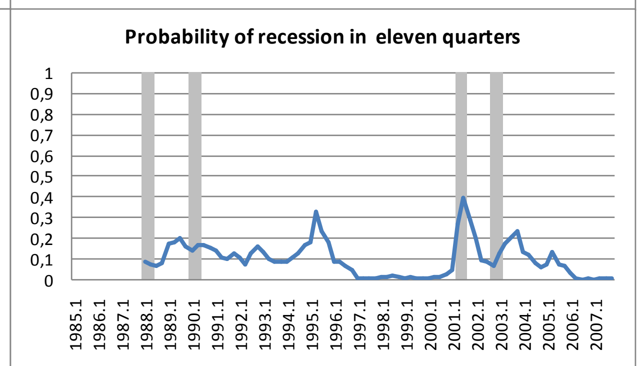
FIGURE 12.5: PROBIT GRAPHS USING THE DOMESTIC AND US TERM SPREAD

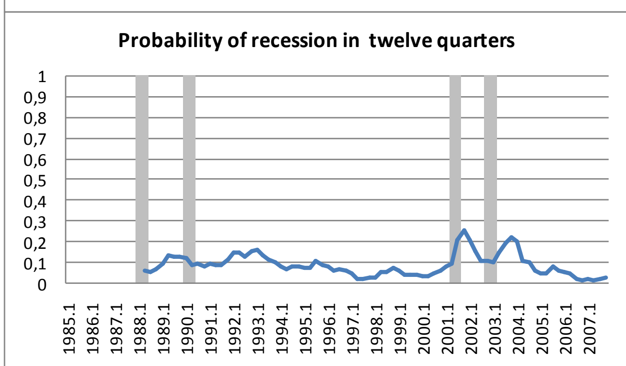


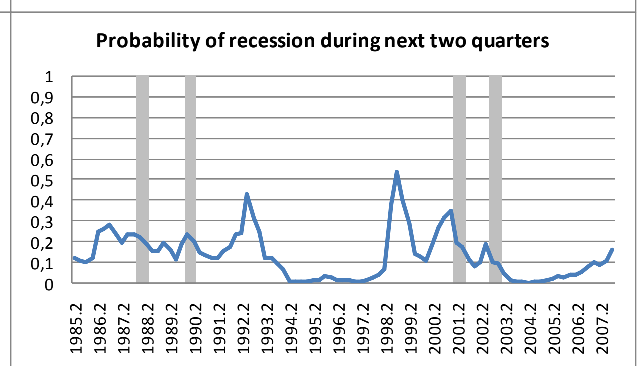

Probability of recession in eight quarters

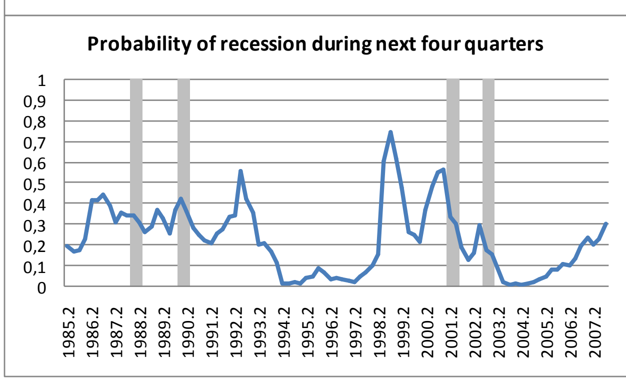

Probability of recession in nine quarters

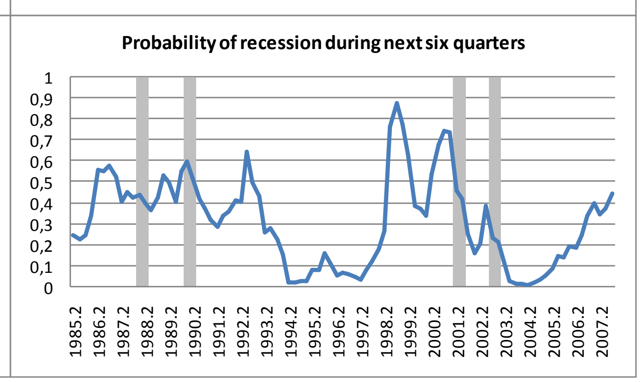

Probability of recession in ten quarters


Probability of recession in eleven quarters


Probability of recession in twelve quarters


Probability of recession during next two quarters


Probability of recession during next four quarters


Probability of recession during next six quarters

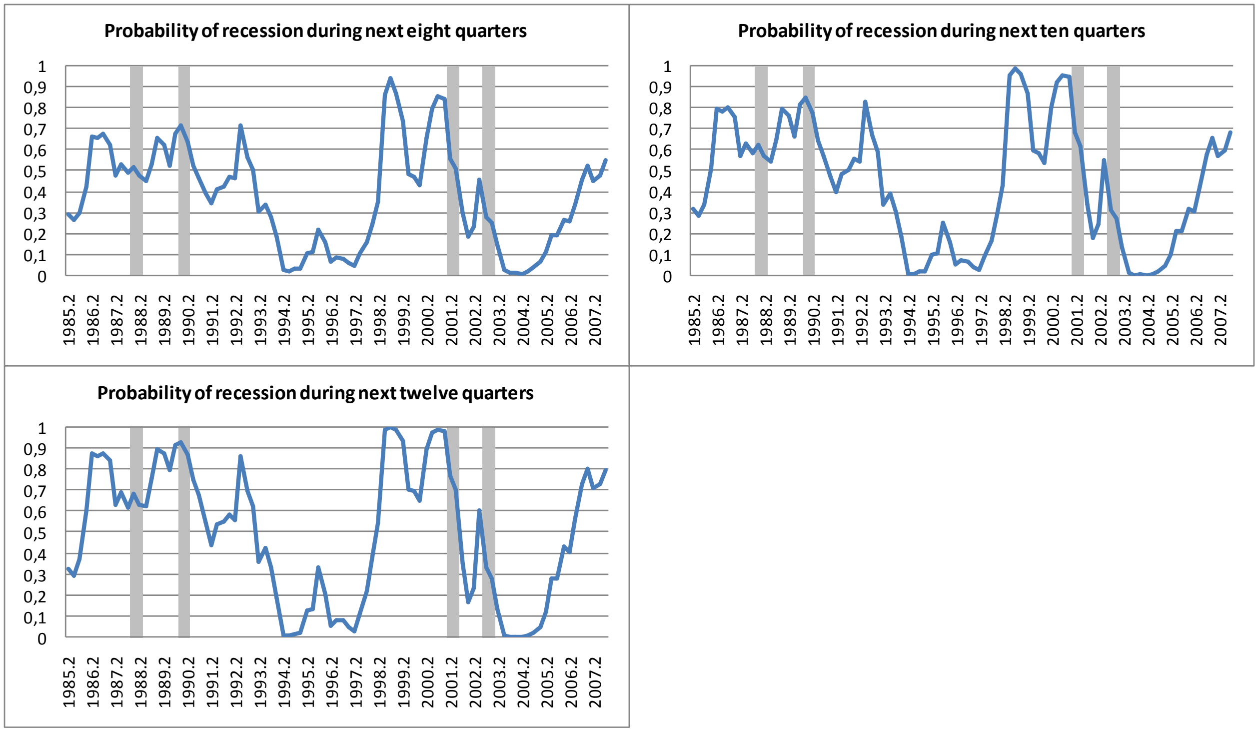
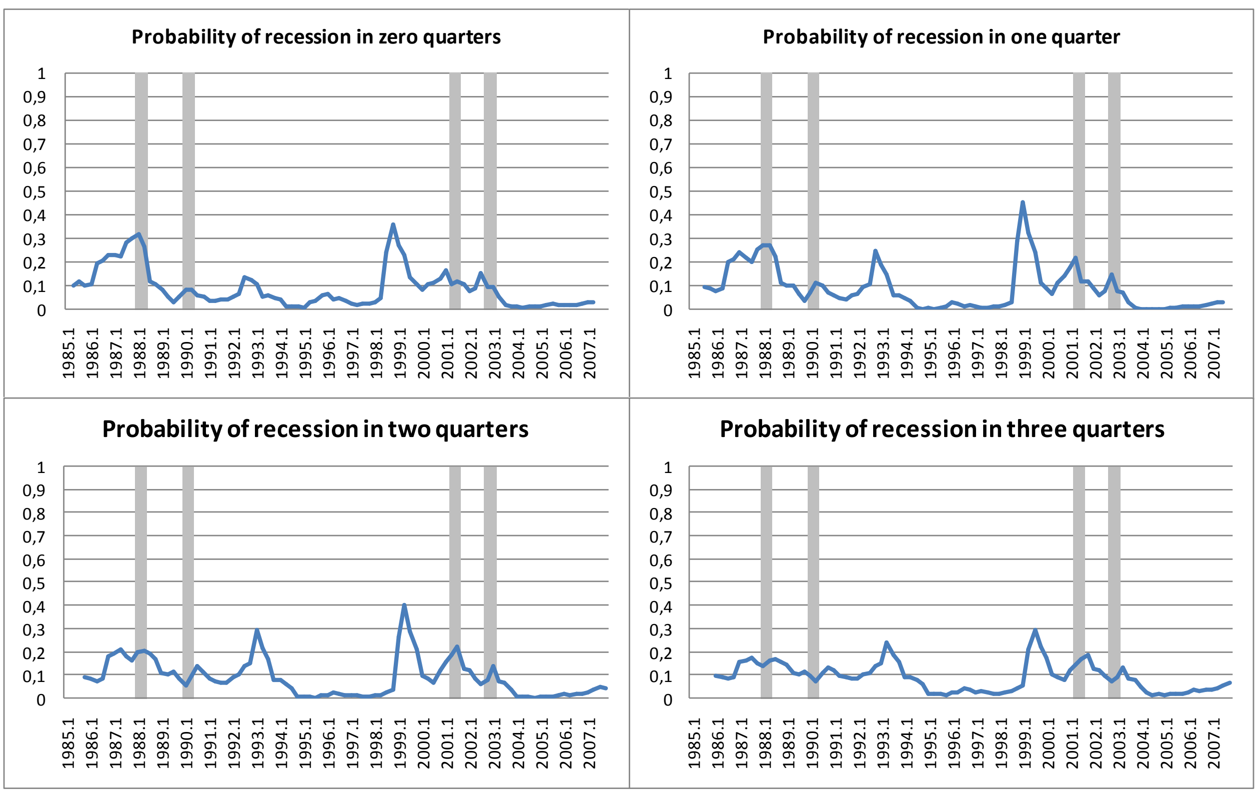
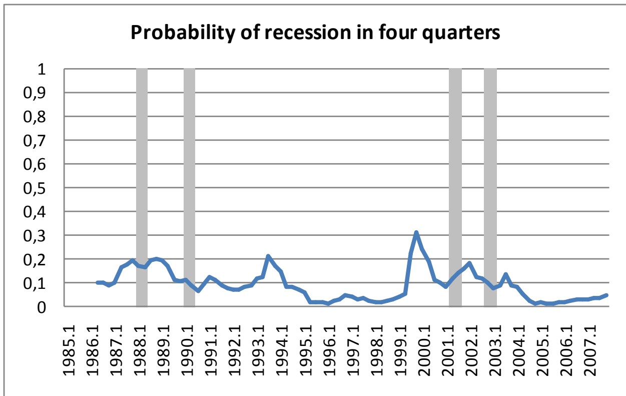
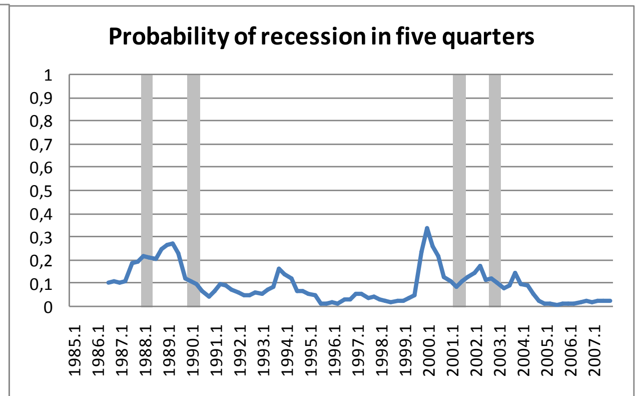
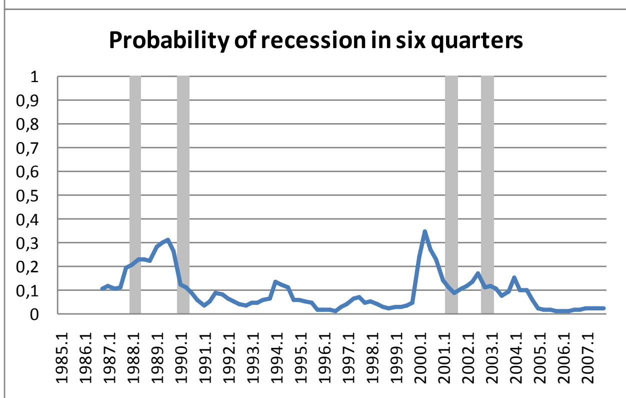


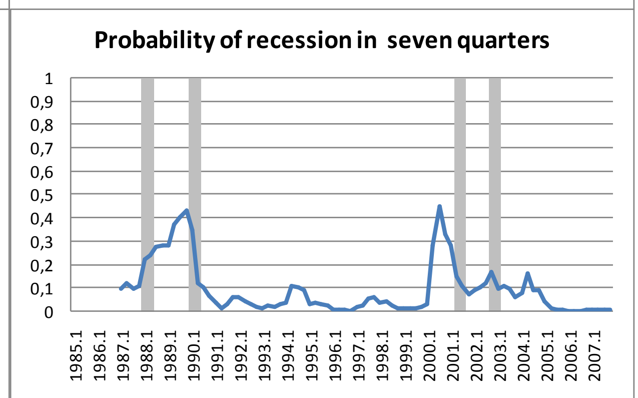
FIGURE 12.6: PROBIT GRAPHS USING THE DOMESTIC TERM SPREAD AND GERMAN TERM SPREAD

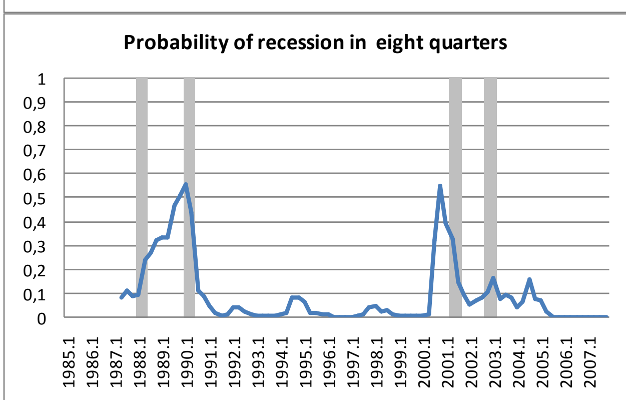


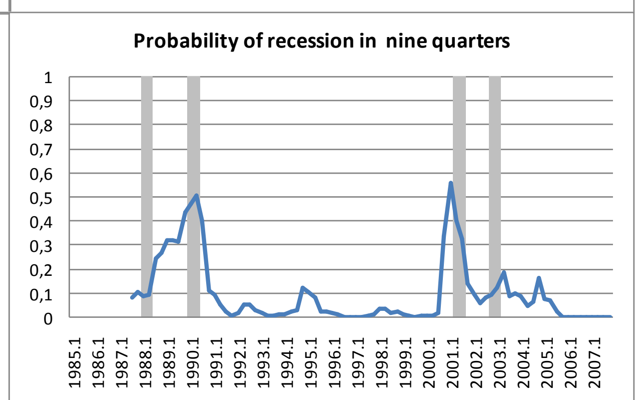

Probability of recession in four quarters
1 0,9 0,8 0,7 0,6 0,5 0,4 0,3 0,2 0,1 0
1985.1 1986.1 1987.1 1988.1 1989.1 1990.1 1991.1 1992.1 1993.1 1994.1 1995.1 1996.1 1997.1 1998.1 1999.1 2000.1 2001.1 2002.1 2003.1 2004.1 2005.1 2006.1 2007.1

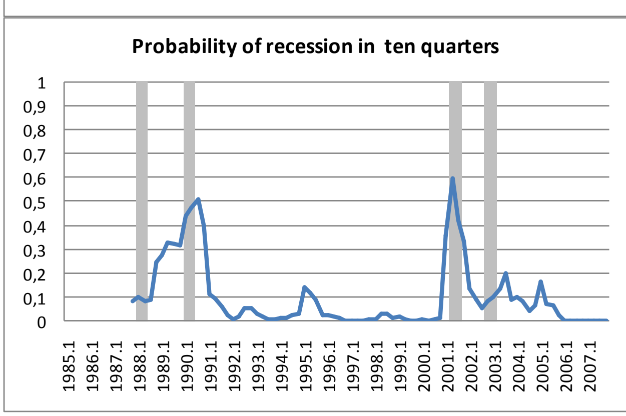

Probability of recession in five quarters
1 0,9 0,8 0,7 0,6 0,5 0,4 0,3 0,2 0,1 0
1985.1 1986.1 1987.1 1988.1 1989.1 1990.1 1991.1 1992.1 1993.1 1994.1 1995.1 1996.1 1997.1 1998.1 1999.1 2000.1 2001.1 2002.1 2003.1 2004.1 2005.1 2006.1 2007.1

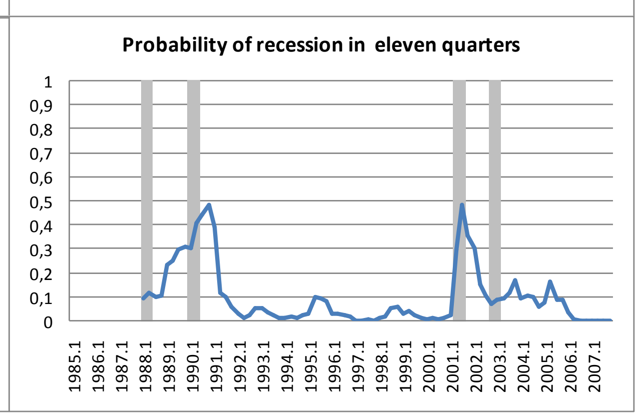

Probability of recession in six quarters
1 0,9 0,8 0,7 0,6 0,5 0,4 0,3 0,2 0,1 0
1985.1 1986.1 1987.1 1988.1 1989.1 1990.1 1991.1 1992.1 1993.1 1994.1 1995.1 1996.1 1997.1 1998.1 1999.1 2000.1 2001.1 2002.1 2003.1 2004.1 2005.1 2006.1 2007.1

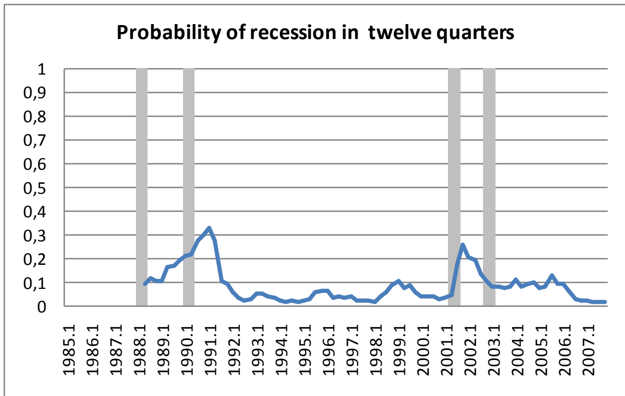

Probability of recession in seven quarters
1 0,9 0,8 0,7 0,6 0,5 0,4 0,3 0,2 0,1 0
1985.1 1986.1 1987.1 1988.1 1989.1 1990.1 1991.1 1992.1 1993.1 1994.1 1995.1 1996.1 1997.1 1998.1 1999.1 2000.1 2001.1 2002.1 2003.1 2004.1 2005.1 2006.1 2007.1

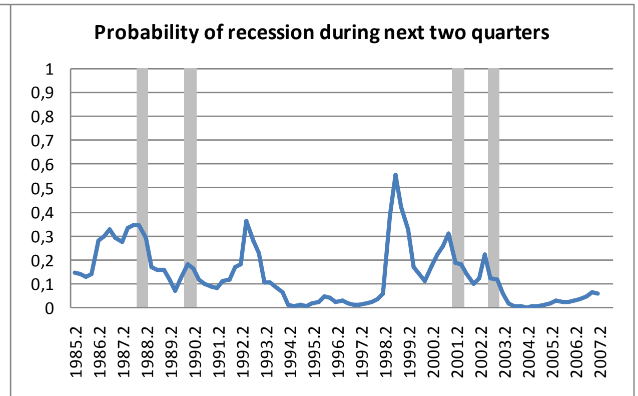

Probability of recession in eight quarters
1 0,9 0,8 0,7 0,6 0,5 0,4 0,3 0,2 0,1 0
1985.1 1986.1 1987.1 1988.1 1989.1 1990.1 1991.1 1992.1 1993.1 1994.1 1995.1 1996.1 1997.1 1998.1 1999.1 2000.1 2001.1 2002.1 2003.1 2004.1 2005.1 2006.1 2007.1

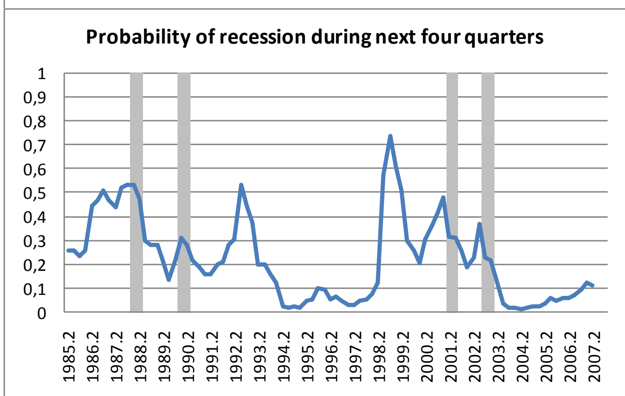

Probability of recession in nine quarters
1 0,9 0,8 0,7 0,6 0,5 0,4 0,3 0,2 0,1 0
1985.1 1986.1 1987.1 1988.1 1989.1 1990.1 1991.1 1992.1 1993.1 1994.1 1995.1 1996.1 1997.1 1998.1 1999.1 2000.1 2001.1 2002.1 2003.1 2004.1 2005.1 2006.1 2007.1

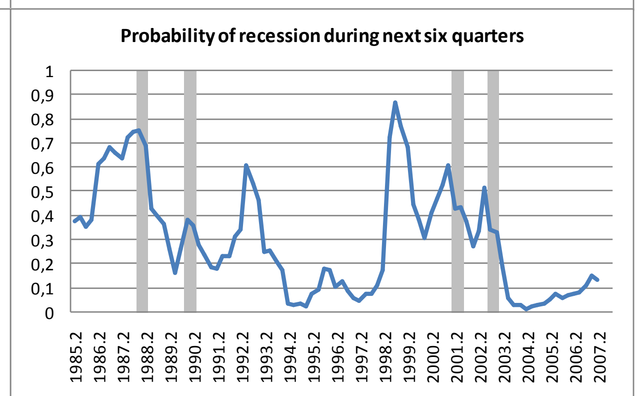

Probability of recession in ten quarters
1 0,9 0,8 0,7 0,6 0,5 0,4 0,3 0,2 0,1 0
1985.1 1986.1 1987.1 1988.1 1989.1 1990.1 1991.1 1992.1 1993.1 1994.1 1995.1 1996.1 1997.1 1998.1 1999.1 2000.1 2001.1 2002.1 2003.1 2004.1 2005.1 2006.1 2007.1

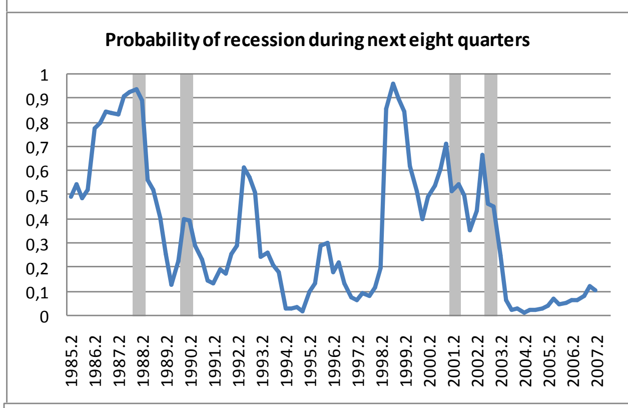

Probability of recession in eleven quarters
1 0,9 0,8 0,7 0,6 0,5 0,4 0,3 0,2 0,1 0
1985.1 1986.1 1987.1 1988.1 1989.1 1990.1 1991.1 1992.1 1993.1 1994.1 1995.1 1996.1 1997.1 1998.1 1999.1 2000.1 2001.1 2002.1 2003.1 2004.1 2005.1 2006.1 2007.1

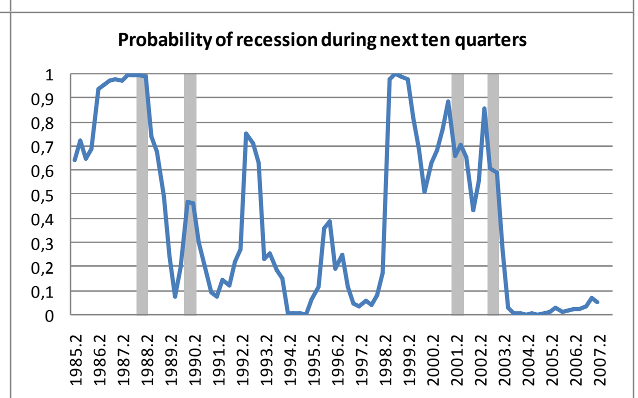

Probability of recession in twelve quarters
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
1985.1 1986.1 1987.1 1988.1 1989.1 1990.1 1991.1 1992.1 1993.1 1994.1 1995.1 1996.1 1997.1 1998.1 1999.1 2000.1 2001.1 2002.1 2003.1 2004.1 2005.1 2006.1 2007.1


Probability of recession during next two quarters
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
1985.2 1986.2 1987.2 1988.2 1989.2 1990.2 1991.2 1992.2 1993.2 1994.2 1995.2 1996.2 1997.2 1998.2 1999.2 2000.2 2001.2 2002.2 2003.2 2004.2 2005.2 2006.2 2007.2


Probability of recession during next four quarters
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
1985.2 1986.2 1987.2 1988.2 1989.2 1990.2 1991.2 1992.2 1993.2 1994.2 1995.2 1996.2 1997.2 1998.2 1999.2 2000.2 2001.2 2002.2 2003.2 2004.2 2005.2 2006.2 2007.2


Probability of recession during next six quarters
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
1985.2 1986.2 1987.2 1988.2 1989.2 1990.2 1991.2 1992.2 1993.2 1994.2 1995.2 1996.2 1997.2 1998.2 1999.2 2000.2 2001.2 2002.2 2003.2 2004.2 2005.2 2006.2 2007.2


Probability of recession during next eight quarters
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
1985.2 1986.2 1987.2 1988.2 1989.2 1990.2 1991.2 1992.2 1993.2 1994.2 1995.2 1996.2 1997.2 1998.2 1999.2 2000.2 2001.2 2002.2 2003.2 2004.2 2005.2 2006.2 2007.2


Probability of recession during next ten quarters
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
1985.2 1986.2 1987.2 1988.2 1989.2 1990.2 1991.2 1992.2 1993.2 1994.2 1995.2 1996.2 1997.2 1998.2 1999.2 2000.2 2001.2 2002.2 2003.2 2004.2 2005.2 2006.2 2007.2

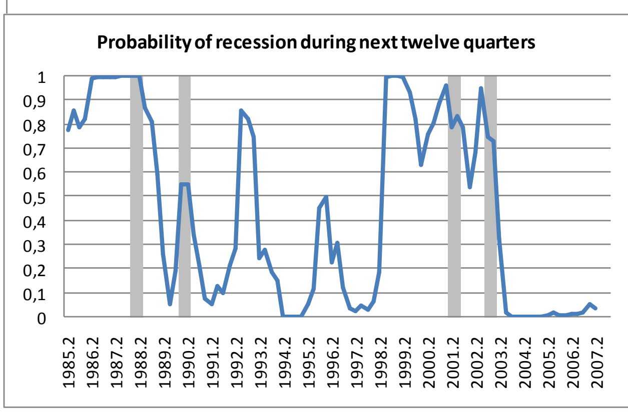
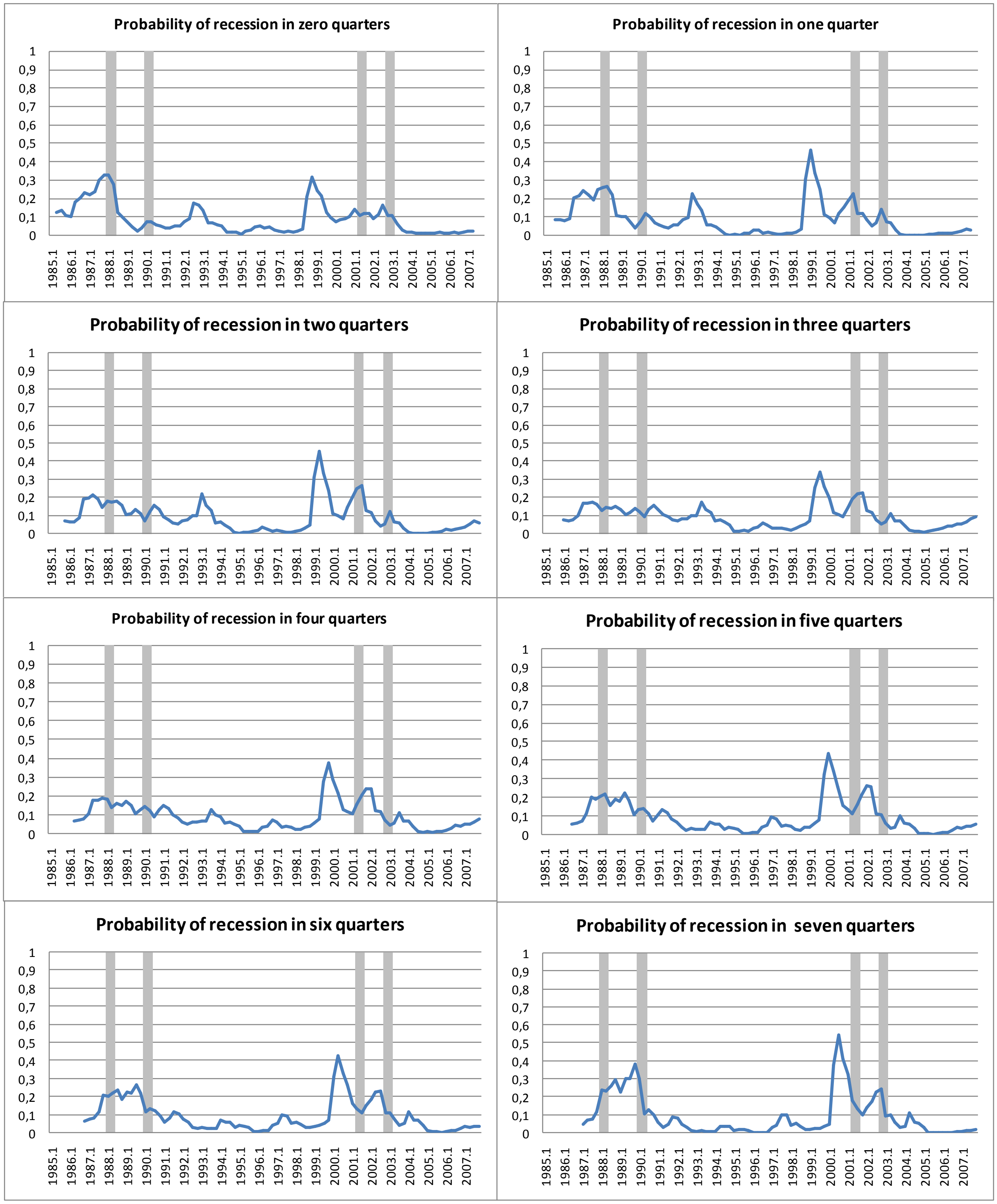
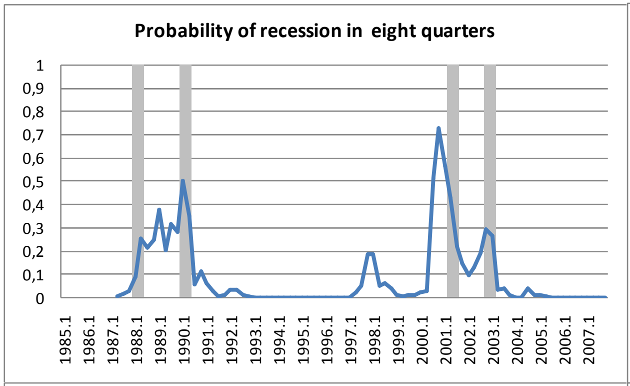
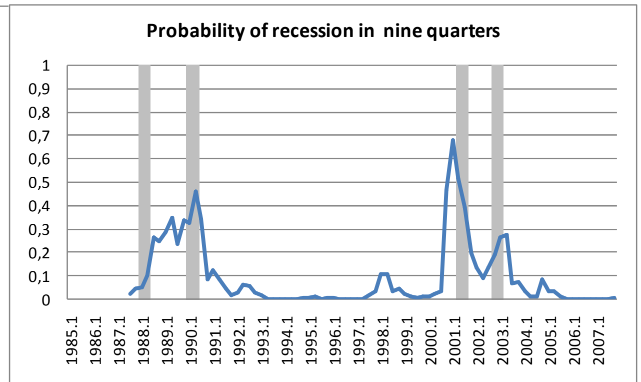
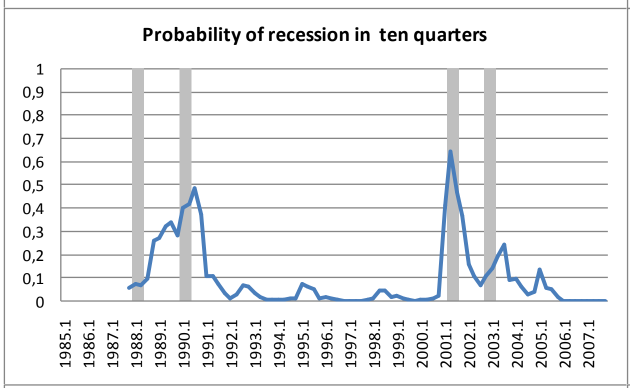

Probability of recession during next twelve quarters
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
1985.2 1986.2 1987.2 1988.2 1989.2 1990.2 1991.2 1992.2 1993.2 1994.2 1995.2 1996.2 1997.2 1998.2 1999.2 2000.2 2001.2 2002.2 2003.2 2004.2 2005.2 2006.2 2007.2

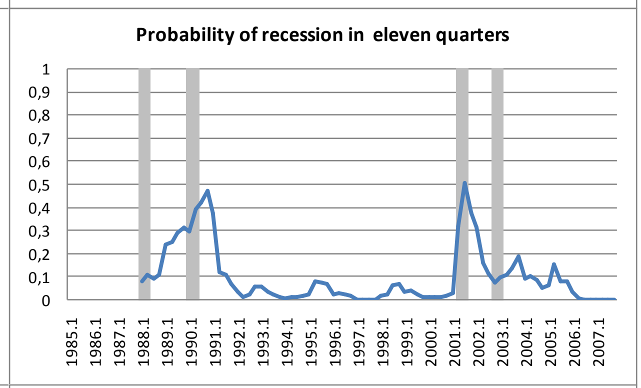
FIGURE 12.7: PROBIT GRAPHS USING THE DOMESTIC, US AND GERMAN TERM SPREAD

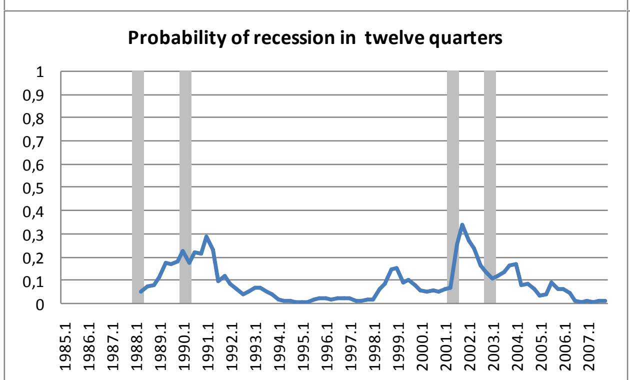


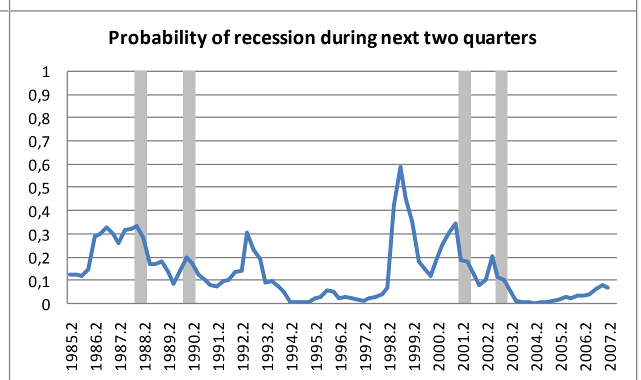

Probability of recession in eight quarters

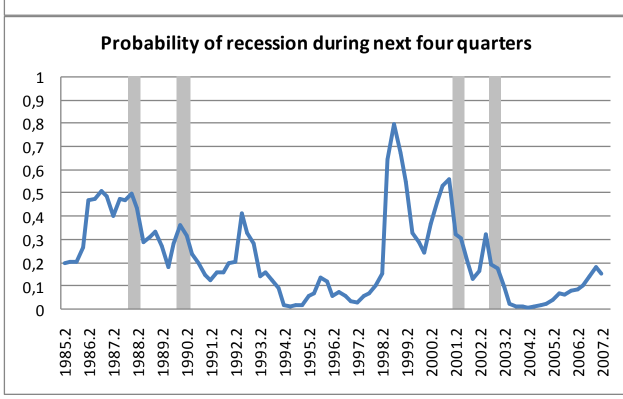

Probability of recession in nine quarters

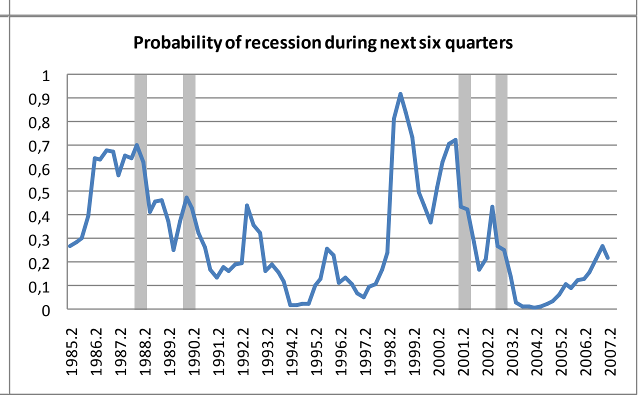

Probability of recession in ten quarters

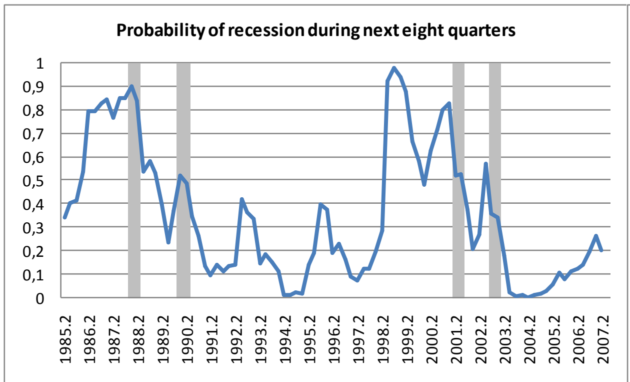

Probability of recession in eleven quarters

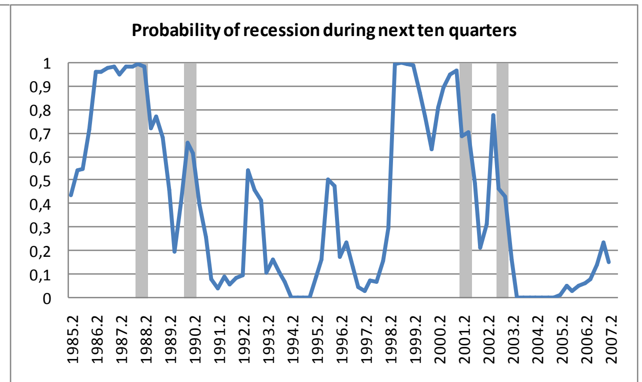

Probability of recession in twelve quarters

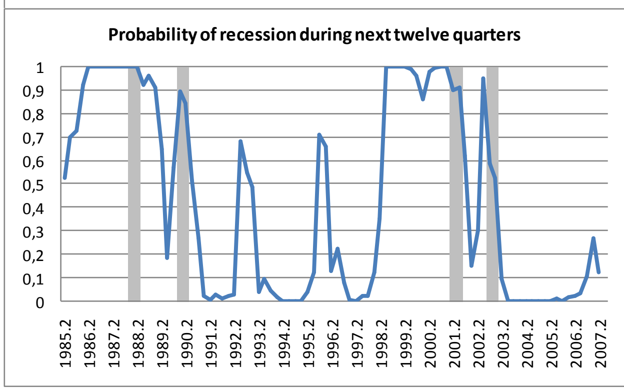

Probability of recession during next two quarters


Probability of recession during next four quarters

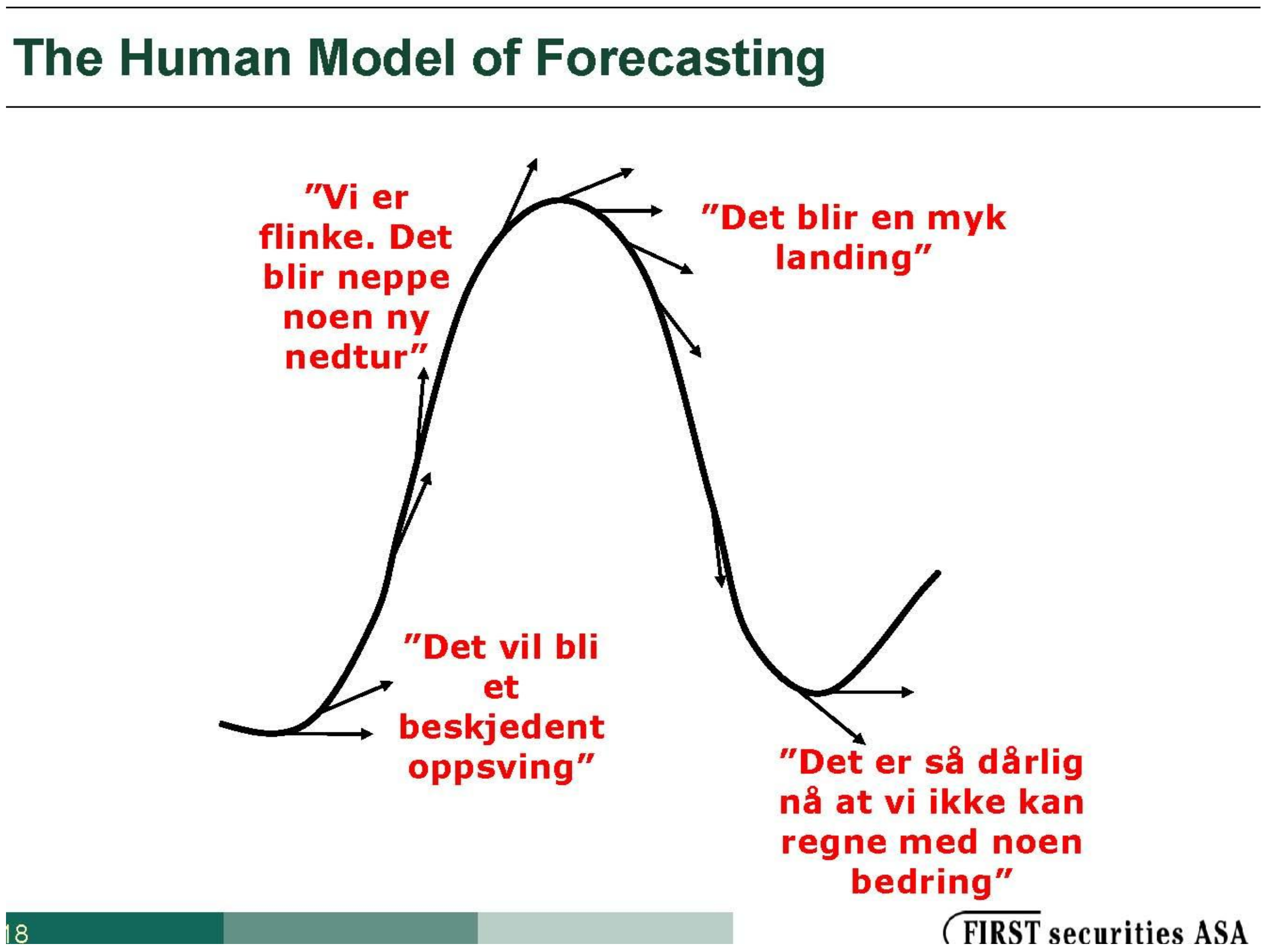

Probability of recession during next six quarters


Probability of recession during next eight quarters
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
1985.2
1986.2
1987.2
1988.2
1989.2
1990.2
1991.2
1992.2
1993.2
1994.2
1995.2
1996.2
1997.2
1998.2
1999.2
2000.2
2001.2
2002.2
2003.2
2004.2
2005.2
2006.2
2007.2


Probability of recession during next ten quarters
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
1985.2
1986.2
1987.2
1988.2
1989.2
1990.2
1991.2
1992.2
1993.2
1994.2
1995.2
1996.2
1997.2
1998.2
1999.2
2000.2
2001.2
2002.2
2003.2
2004.2
2005.2
2006.2
2007.2


Probability of recession during next twelve quarters
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
1985.2
1986.2
1987.2
1988.2
1989.2
1990.2
1991.2
1992.2
1993.2
1994.2
1995.2
1996.2
1997.2
1998.2
1999.2
2000.2
2001.2
2002.2
2003.2
2004.2
2005.2
2006.2
2007.2

Appendix 12.8 The human forecasting model



Source: Harald Magnus Andreassen (2007).