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Informational Content of the Yield Curve and the Crisis

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1 Introduction

Economists are often interested in clear and simple indicators which show the mood of the economy and the possible future developments of it. Not only economists, also investors and policy makers pay a huge attention on such indicators, as they can influence their decisions. The yield curve has developed to such an instrument. Today it is "[...] a good indicator of the bond market's expectations for the economy."[1] Studies on the yield curve are widely common in investment companies, in the public sector and in science. The yield curve can for example give information of the future development of economic activities, of expected inflation and more. Like most economic theories and models, also the theoretical way of thinking about the yield curve can not get along without assumption and conditions, like full information of the subjects, rationality, being in equilibrium and so on.

Since 2007 we have been facing one of the biggest financial crises ever and in Europe there is also a debt crisis of sovereign countries going on. Some investment companies broke down – others have to be rescued by governments. The whole economic cycle has seriously been disrupted and has not come back to its equilibrium path until now. In times of a financial crisis the cycle of lending and borrowing funds collapses because of a sudden increase in moral hazard and adverse selection. An efficient functioning of the financial market is inevitable for the whole system of the economy. During a crisis the efficiency of the system is interrupted and uncertainty throughout all market participants increases (Mishkin 2004).

There are reasons to believe that the developments from 2007 until now do have an effect on the assumption and theoretical aspects of the yield curve. It may be that the conclusions one can draw from the yield curve are not the same than in times without a crisis. Due to the lack of certainty and information, market participants may give incorrect signals, which may have a negative influence on the yield curve's power to indicate expectations. In Europe there is an even more dramatic situation as the European Central Bank (ECB) practiced market interventions on a historically grand scale. The ECB acted against their mandate of the European Treaties, which is just the inflation targeting, with non-standard monetary policy measurements. With the quantitative (or credit) easing programs the ECB not only bought high risk bonds from commercial banks but also government bonds. These activities may decrease the yield on bonds as the risk of such papers went down, it sustain a high demand on that assets and may decrease the real rates (Krishnamurthy/Vissing-Jorgensen 2001). Other possible consequences from that non-standard program of the ECB are the risk of higher inflation rates and that there is a transfer of risk from sovereign countries to the taxpayers (as

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[1] http://www.franklintempleton.co.uk/jsp_cm/funds/pdf/FTIAFI_YC_0109_Web.pdf (14.03.2012)

the member states are liable for the ECB). With the latter the ECB helps countries to come through their debt problems, which by treaty is not their pattern (Tempelman 2012). By buying governments bonds the central banks make debt financing cheaper and acts therefore as a fiscal policy maker (ibid.). When the ECB decreases the dependency from politics (which is or would be guaranteed by treaties) it runs the risk of losing credibility. All in all there may be negative effects on market participant's expectations caused by the credit easing programs (Krishnamurthy/Vissing-Jorgensen 2011).

Because of the described reasons, there may be a disruption in the role of the yield curve as an adequate indicator for depicting market's expectations. This work wants to answer the question whether the crisis and the accompanying measures and developments have an influence on the informational content which can be extracted from the yield curve. The main assumption and idea is that the crisis has a negative influence on standard models and premises of the yield curve as an indicator for future developments. This work should also give a brief overview of the main theoretical aspects and models on the yield curve. It should further analyze the ways how to extract information of expectations on future activities. For few standard models an empirical study with Austrian Bond data should find evidence for the main assumption. This should be done by splitting the sample into two parts – one before the crisis and one since the beginning of the current crisis – and comparing the results of both parts.

This thesis is organized as follows: The first section (Ch. 2) explains the theoretical background of interest rates and the term structure of an asset. After that a description and some main theories of the yield curve (Ch. 3) follows. How to model the yield curve is the last part of that section. The third section (Ch. 4) is the main part of the thesis. It explores the possible ways how the yield curve can act as an indicator for future developments. The empirical studies for answering the research question are immanent in those chapters after each theoretical part.

1.1 Data

The data of the yield curve has been taken from the Österreichische Kontrollbank (OeKB) and are on a daily basis.[2] Each observed day reflects implicit forward rates of the term structure of Austrian government bonds computed by the OeKB. The term structure reports the yield of every observed day for several maturities. These implicit rates of the bonds are made as if they were zero-coupon bond without any default risk. The sample goes from 4.1.1993 to 17.4.2012 and includes every trade day for Austrian bonds. In sum the sample includes 4783

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[2] Thanks to the colleagues of the OeKB who gave me access to the database of www.profitweb.at

observed days. Every day includes the bond yield of maturities of 6, 12, 18, 24, 30, 36, 42, 48, 54, 60, 66, 72, 78, 84, 90, 96, 102, 108, 114 and 120 months.

The data for the GDP growth rates have been taken from the OECD statistics service.[3] These growth rates – which are based on a quarterly basis – report the gross domestic product (expenditure approach) compared to that of the previous quarter. The first observation is 1993 quarter 1 and the sample ends in 2012 quarter 1.

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[3] http://stats.oecd.org

2 Definitions and understanding interest rates

2.1 *What is an interest rate?*

There is – as in many economic concepts – no single definition of an interest rate. The concept behind an interest rate is, if someone borrows money from another person, this person wants to have a compensation for lending him her money. This is because the lender could do other things with his money like buying some consumption items or investing it elsewhere. In general an interest rate is therefore "[a] rate which is charged or paid for the use of money".[4] A textbook definition might be: "The interest rate is the yearly price charged by a lender to a borrower in order for the borrower to obtain a loan. This is usually expressed as a percentage of the total amount loaned".[5]

In order to fully understand the idea of an interest rate one has to introduce the concept of a *present value*. The idea is that a Euro today is less worth than a Euro next year. This is because by depositing this Euro today one gets more than one Euro next year, as we have seen above one gets an interest payment for lending money. If we consider a simple loan it becomes clearer (see Mishkin 2004): A person takes a simple loan of 100 Euros from her friend and promises to pay back this 100 Euros (called the principal) with an additional interest payment of 10 Euros in one year. One can calculate the (simple, nominal) interest rate by dividing the interest payment with the principal:

$$i = \frac{10}{100} = 0.1 = 10\%$$

The loan of 100 Euros gives a future value (in one year) of 110 Euros, which can be called the *cash flow* and it is calculated as follows:

$$100 * (1 + 0.1) = 110$$

If the lender does not need the money after this year, she can give out another load for one year (with a new value of 110 Euros). Therefore the lender will get 10 Euros interest payment for the fist year and another 10 percent interest for the new principal of 110 Euros. This will lead to the following cash flow:

$$[100 * (1 + 0.1)] * (1 + 0.1) = 100 * (1 + 0.1)^2 = 121$$

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[4] http://www.investorwords.com/2539/interest_rate.html (13.06.2012)
[5] http://economics.about.com/cs/economicsglossary/g/interest_rate.htm (13.06.2012)

This process could last for n years and ends up with a generalized cash flow of this 100 Euro loan like this:

$$100 * (1 + 0.1)^n$$

Vice versa one could also calculate the present value of the loan for a cash flow of 121 Euros (again considering a simple loan for 2 years with an interest rate of 10 %):

$$100 = \frac{121}{(1 + 0.1)^2}$$

This process is also called discounting the future and lead to the general formula of present values:

$$PV = \frac{CF}{(1 + i)^n} \tag{1}$$

where PV stands for present value, CF for cash flow (or the future value) and i for the corresponding interest rate.

Interest rates are very important indicators for financial markets and the whole economy. They influence private decisions, whether to save money or to spend it for different uses. When the interest rate level is very high people tend to save more money as there are higher incentives due to sizeable profits. If one wants to buy a house and is therefore taking a loan, high interest rates are bad news and this person may decide not to buy it now. Not only household's decisions are influenced by interest rates, but also those of firms or governments. In times of low interest rates it is more attractive for those actors to invest into new equipment etc. by borrowing money than in times with high interest rates (cf. Mishkin 2004). For financial markets there are other reasons according to the importance of interest rates. Not only bonds but all financial derivatives are sensitive to interest rates. Also the pricing for different market securities is linked to interest rates. Most investment decisions are based on the cost of borrowing money and the expectations of alternatives which in fact depend on interest rates (Irturk 2006). In sum one can say that: "Interest rates will affect ALL financial markets, including but not limited to, stocks, bonds, futures, forex, options etc."[6]

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[6] http://www.dailymarkets.com/forex/2006/08/07/why-interest-rates-are-so-important/ (13.06.2012)

In public opinion and newspapers one can often hear the term of one (single) interest rate. This is not true, as there is an interest rate for each of the many financial instruments (like for bank deposits, for private/commercial loans, public bonds etc.). In fact there are couple of different interest rates, where some are more important as a leading interest rate for the economy (like the Euribor interest rate) than others.

Another substantial matter to distinguish is the term nominal and real interest rate. Economists talk about nominal terms, when they are thinking of terms in absolute (often monetary) values, whereas for real terms they adjust for inflation. If we consider the interest rate of a bank deposit – which denotes at e.g. 4.5 % – and an (expected) inflation rate of 2 %, the real interest rate would be 2.5 %. For economists real interest rates are often more interesting to focus on, as they can express individuals' consumption abilities.

2.2 Yield to maturity

As we can distinguish more than just one debt instrument in financial markets, with different maturities, payments and other modalities, economists like to have a measurement of an interest rate which is comparable. The *yield to maturity* is a common way to measure the interest rate of an investment or debt instrument which takes into the account the cash flows, the different current prices (and therefore the potential capital gain or loss) and the difference in the length of an asset (Pilbeam 2005). The yield to maturity calculates "[…] the interest rate that equates the present value of payments received from a debt instrument with its value today" (Mishkin 2004: 64). So it determines the implicit interest rate of a discounted payment stream and the price of the asset as its present value.

For a simple (one year) loan like above, the yield to maturity equals the simple nominal interest rate. Considering a coupon bond or a fixed-payment loan the calculation is different. A fixed-payment loan is a loan where one has to pay a fixed amount every period during the whole maturity. Following the same modality despite a current (changing) price, describes a coupon bond. The yield to maturity can be calculated as follows:

For a fixed-payment loan, which lasts for 2 years and has 80 Euros annual payment, one sets the face value (present value) of e.g. 1000 Euro equal to the payment stream, where at the end of the last period the face value has to be paid back.

$$1000 = \frac{80}{1+i} + \frac{80}{(1+i)^2} + \frac{1000}{(1+i)^2}$$

Rearranging and using the formula of quadratic functions implies:

$$1000*(1+2i+i^2) = 80*(1+i)+1080$$

$$1000i^2 + 1920i - 160 = 0$$

$$i_{1,2} = \frac{-1920 \pm \sqrt{1920^2 + 4*(1000*160)}}{2000} =$$

$$i_1 = 0.08 \quad i_2 = -2$$

The yield to maturity for this loan is 8 % (as we can neglect the negative solution).

In general one can compute the yield to maturity for an asset that has n periods to the end of maturity and an actual price by the following formula:

$$P = \frac{CF_1}{1+i} + \frac{CF_2}{(1+i)^2} + \frac{CF_3}{(1+i)^3} + ... + \frac{CF_n}{(1+i)^n} + \frac{F}{(1+i)^n} \qquad (2)$$

where P is the current price of the asset, CF_n the cash flow in each period and F the face value.

The computation for long maturities might not be that easy, but there are mathematical tools and calculations for doing so. One can see from (2), if the price of an asset rises, the yield to maturity has to go down and vice versa. Intuitively this is obvious that one's return is lower when paying a higher price for an asset (and getting the same fixed payments), whereas for lower prices the percentual winning or return[7] is higher. One important fact on the yield to maturity is therefore that the price of an asset is negatively related to its interest rate (Mishkin 2004).

A proper approximation of the yield to maturity is the so called *current yield*. In contrast to the yield to maturity it is easy to calculate by just dividing the yearly cash flow by the price of the asset. The current yield is just a simple form of measuring an interest rate and a more useful measure if the asset has a long time to maturity, as the effect of a capital gain or loss is decreasing (Pilbeam 2005).

The yield to maturity is "the most accurate" way of measuring the interest rate (Mishkin 2004: 69), therefore these two expressions will be used synonymously further on in this work.

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[7] The return of an asset need not be equal to the yield to maturity. The rate of return takes into the account the change in an assets' value (as price changes) and gives therefore a measurement of how well an investor is off by investing into a certain security (cf. Mishkin 2004).

2.3 The risk and term structure of interest rates

Financial markets distinguish between many different interest rates or yields, as have been seen before. Here we shortly want to explore the reasons for that, which are commonly described by the differences in the risk of an asset.

Differences in the yields of bonds (and other assets) with the same maturity are often explained by differences in the *risk structure*. The interest rates of two government bonds for example can be quite diverse and also vary over time. The reason for this is because every bond has a specific *risk of default,* that is, when an issuer of a bond (in that example the government) is not able or willing to make interest payments or paying back the face value (Mishkin 2004). As you can see in figure 1 there are huge variations in 10-year government bonds over some Euro-area countries. After the introduction of the Euro, investors handled the government bonds of all Euro-countries as if they were the same, but after the financial and debt crisis in recent years they have rediscovered the differences in the risk structure of those states.
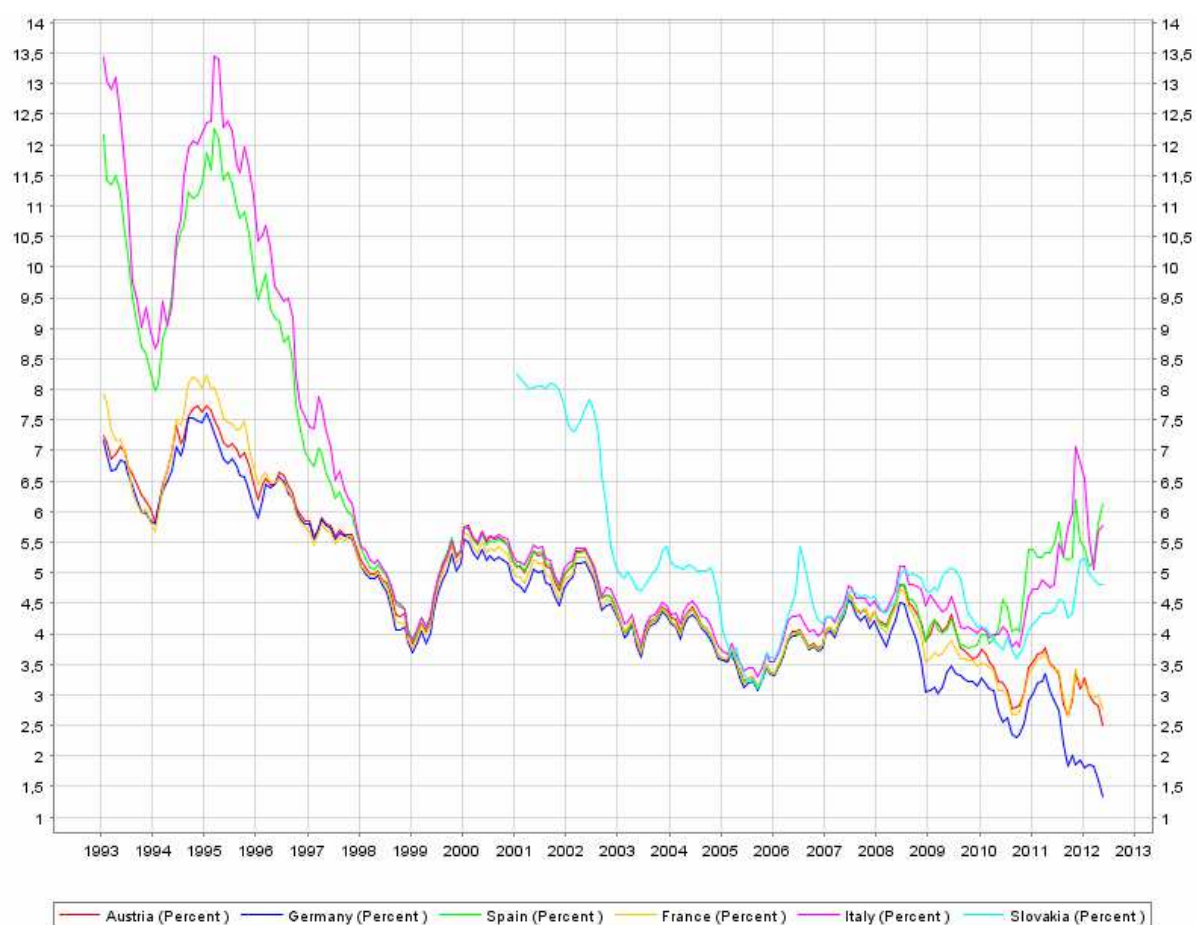

Figure 1 – Long term bond yields of some European Countries
Source: ECB; http://sdw.ecb.europa.eu/browseChart.do? (02.07.2012)

Mishkin (2004) treats government bond (and especially US Treasury bonds) as financial assets without any major default risk, as governments always can increase taxes to fulfil their obligations.[8] By comparing the yield of a risk-free bond with that of a risky one (but having the same maturity), the spread between those two interest rates is called the risk premium. Investors determine the height of a risk premium (the compensation of running a higher risk) by macroeconomic data of a country, by the general assessment of default risk and with the help of rating agencies. These are professional companies that explore the default risk of countries but also companies. The leading rating agencies are Moody's, Standard & Poor and Fitch. They grade corporations and governments from AAA (highest quality, lowest default risk) to C or D ratings (default). The intermediate ratings depict their expected risk of a default (e.g. A1 or A+ upper medium grade, Ba1 or BB+ speculative). In the debt crisis these rating agencies have been heavily criticised by European politicians and there was the call for a new, European rating agency.[9]

Other reasons for the differences in the yield of assets with the same maturity are the variations in liquidity and the income tax consideration (ibid.). Investors feel safer if they can convert their securities into cash very fast. Government bonds are typical examples for assets which have a very large market and one can find a buyer easily, whereas for corporate bonds it might be more difficult. Because of this risk investors demand a higher yield, the liquidity premium (or most of the time it is simply included in the risk premium).
If an investor invests into an Austrian bond he has to pay 25 % income tax from his interest payments. In other countries with lower taxes he would have made a higher effective income, ceteris paribus. By comparing different bonds the income tax consideration is therefore a not neglectable issue, as investors want to have a compensation for higher taxes in the interest rate.

If two bonds have the same risk structure, the same liquidity and income tax consideration (are therefore perfectly comparable), they can differ in their time due to maturity. This so called term structure has a major influence on the yield and determines the yield curve, which will be the subject of the next chapter.

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[8] Nowadays this point of view might not be true or is even discussable.
[9] http://www.reuters.com/article/2012/01/21/us-berger-ratingagency-idUSTRE80K0GL20120121 (02.07.2012)

3 The Yield Curve

3.1 What is it?

Bonds and other assets can vary in a couple of matters, as has been shown in the last chapter. One point of view to explore bonds is the term structure of the interest rate. Comparing bonds which have the same characteristics (like risk structure, liquidity etc.) can be done through the remaining time to mature. One can distinguish between short run and long run bonds or between 3 month and 12 month bonds. A graphical visualization of the interest rates of a bond due to its different maturities is called a yield curve. A textbook definition could be as followed: "A plot of the interest rate charged against different terms to maturity for a bond that is identical in all other respects is known as a yield curve […]" (Pilbeam 2005: 85). Another one: "A plot of the yields on bonds with differing terms to maturity but the same risk, liquidity, and tax considerations is called a yield curve, and it describes the term structure of interest rates for particular types of bonds, such as government bonds" (Mishkin 2004: 127).

In theory the yield of a т period discount bond is a weighted average of forward rates and can be expressed in its continuous form by the following formula (cf. Diebold/Li 2003):

$$y_t(\tau) = \frac{1}{\tau} \int_{t=1}^{\tau} f_t(u)du \tag{3}$$

where the forward rate is the change effect in the price of the present value of such a т period bond a time t.

$$f_t(\tau) = \frac{-P_t^{'}(\tau)}{P_t(\tau)}$$

Plotting all the different yields of a bond for all possible maturities describes the yield curve. Of course this is not observable in reality, so this curve has to be estimated. How to model and estimate the yield curve will be described later.

3.2 The shape of the Yield Curve

In theory, but also empirically, one can monitor different yield curves according to their shape. A yield curve can have a positive or upward sloping curvature, it can be downward sloping, flat or humped shaped.
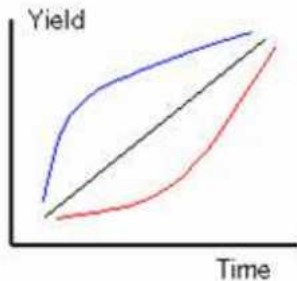

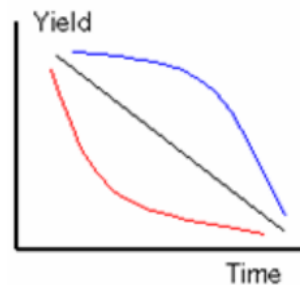**Figure 2** – Upward sloping
Source: Irturk (2006: 6)

Figure 3 – Downward sloping
Source: Irturk (2006: 8)

An upward sloping or positive sloped yield curve (figure 2) indicates that the short term interest rates for bonds are lower than the long term ones. Usually short term yields are below long term yields as the uncertainty (also caused by inflation) increases in time. Therefore a yield curve with such a shape is also called a normal yield curve. A downward sloping, negative sloped or inverted yield curve (figure 3) implies that the short term interest rates are above long term rates. Because of the higher risk of long term capital a negative shape of the yield curve is not "normal" and is often the case when investors expect the yield to decrease.
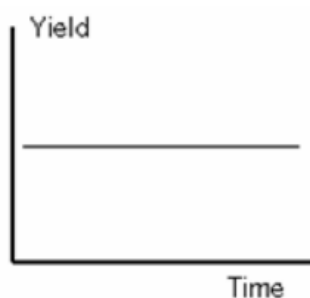
Figure 4 – Flat
Source: Irturk (2006: 9)
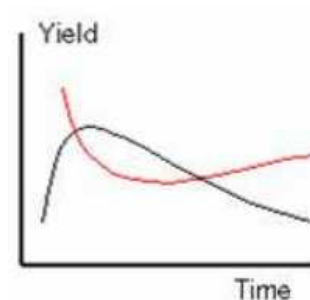
Figure 5 – Humped shaped
Source: Irturk (2006: 10)

A flat yield curve like in figure 4 gives the information that the short term yield is equal to the long term yield of a bond. The last possible curvature of a yield curve is the humped shaped one. Like in figure 5 one can see that markets give different information. On the one hand the short run yield is nearly at the same level than the long run yield, in between the interest rate is volatile. This implies that investors expect an increase of medium run yields, so that it first

rises during a period and then falls in another period. On the other hand the market could expect a fall of the yield in a period, which is followed by an increase in the next period (started at a high level of interest rate).[10] Such a change in the shape of the curve is called twist (Irturk 2006).

Beyond these (theoretical) examples of variations in the yield curve – which of course can be seen in reality – there are three major empirical observations economists made due to the form of the curve. These stylized facts are (cf. Mishkin 2004, Irturk 2006):

Fact 1: Yields of bonds with different maturities move together over time.

Fact 2: If the short term interest rate of a bond is low, it is more likely that the yield curve has an upward slope; respectively if the short term yield is high, it is more likely that the curve has a downward slope or is inverted.

Fact 3: In general yield curves have almost always an upward sloping curvature.

Now the question, if there is a theoretical framework that can explain this behavior of the shape of yield curves, arises. A precise theory must be able to explain all the empirically observed facts. Indeed there are mainstream theories on the yield curve, which are topic of the next session.

3.3 Theories on the Yield Curve

3.3.1 Expectations Theory

Interest rates are very volatile, as one can see from the empirical observations above or just by looking at the graph of the yield development of government bonds. No one knows whether the interest rate for an Austrian government one year bond stays the same for the next year(s). Often short term yields are expected to be different in future (Mishkin 2004), as from above we know that interest rates move together over time.

The expectations theory says that an investor is indifferent between a couple of short term investments (i.e. bonds) and one corresponding long term bond. Investors treat bonds of different maturities like perfect substitutes, which is the main assumption in this theory (Pilbeam 2005). For a better understanding let's have a look at an example:

An investor has the choice of investing funds first into two one year bonds, purchasing one at the beginning of the first period and after one year, when the maturity is over, buying another

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[10] All these shapes of the yield curve do not only describe effects on interest rates of varying maturities, they can also be considered due to macroeconomic implications, which will be part later on.

one year bond or second buying now a two year bond and hold it until maturity ends. Let's say the first one year bond gives a 5 percent yield and the second a 7 percent yield. The theory now says that the investor is indifferent between those 2 one year bonds and the two year bond if the yield of the two year bond is 6 percent. Therefore the yield of the long term bond must equal the average of the (expected) short term interest rates. Technically speaking the expectations theory let an investor be indifferent, if the implied forward rates are equal to the expected spot rates (Irturk 2006). A forward rate is defined as an implicit return by buying zero-coupon bonds[11] with different maturities at the same time, whereas a spot rate is an observed yield at any time in the market (Wasmund 1999).

If one denote i_t as today's interest rate of a one period bond, i_{t+1}^e as the expected interest rate of a one year bond in the next period and i_{2t} as today's (at time t) yield of a two period bond the expectations theory of the simple example above can be expressed through the following formula:

$$i_{2t} = \frac{i_t + i_{t+1}^e}{2}$$

In general the theory can be formulated like this (see Mishkin 2004, Pilbeam 2005):

$$i_{nt} = \frac{i_t + i_{t+1}^e + i_{t+2}^e + ... + i_{t+(n-1)}^e}{n} \tag{4}$$

where the interest rate of a n period bond at time t has to equal the average of expected one year bonds.

The expectations theory is also called the pure expectations theory as it has strong assumptions. By combining short term bonds with longer term bonds of the same period, where the total interest earnings have to be the same, the (pure) expectations theory allows to interpret the yield curve as a vehicle to measure the future interest rate development (Irturk 2006).

Empirically one can say that short term interest rates are at a higher level in near future if they rise today (Mishkin 2004). When people's expectation about upcoming short term rates are increasing, short term yields will raise and because of (4) also long term yields will rise – as the long run interest rate is the average of the expected short run rates. This has the effect that short and long run yields move together over time and therefore the expectations

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[11] A zero-coupon bond is a bond which is sold below the face value and repurchased at the face value (so no coupon payment is made).

theory perfectly explains fact 1 (Irturk 2006) of the above stylized facts. This theory can also explain fact number 2. When the short run interest rates in the yield curve are below the long run yields (normal case) markets expect higher short run interest rates in future. The other way round, if the short run yields are above the long run yields, investors expect decreasing short run rates in future (ibid.).

The only disadvantage of the expectations theory is, that it cannot explain fact 3, which says that yield curve usually have an upward slope. For this reason we want to explore the next theory on yield curves.

3.3.2 Segmented Markets Theory

In this theory market participants are assumed to have clear preferences on the maturity of bonds (or assets) because there are barriers of switching between short, medium or long term investments like transaction costs and more (Pilbeam 2005). The markets for bonds of each maturity are separated or segmented and investors do not see bonds with different maturity as substitutes. For this reason "[…] the expected return from holding a bond of one maturity has no effect on the demand for a bond of another maturity" (Mishkin 2004: 132). If the markets are segmented, empirical observations have shown that investors prefer to have a more liquid portfolio (Irturk 2006) because the longer the investing period is the higher the uncertainty is. The demand for short term bonds in that way of thinking has to be higher which corresponds to lower yields and vice versa, with long term bonds one can receive higher yields.

That theory perfectly describes the third fact of the stylized facts on yield curves. The segmented market theory can explain fact 3 but cannot explain fact 1 and 2. A theory which tries to combine both mentioned theories is the next one.

3.3.3 Liquidity Premium Theory

This theory is more or less a development of the expectations theory, an "offshoot" of it (Irturk 2006), which integrates the market segmentation theory. As in the segmented market theory investors prefer investments of shorter periods because of a lower interest rate and liquidity risk. Assuming that financial market participants are in general risk averse, they ask for compensation when they put money into longer term investments, a risk or liquidity premium (cf. Pilbeam 2005). Borrowers by contrast prefer long term credits as the have higher planning security and therefore are willing to give a premium for that (Wasmund 1999). The assumption in this theory is that investors do not see bonds with varying maturity as perfect substitutes but as substitutes (Mishkin 2004).

The risk aversion – or liquidity preference – causes systematically greater forward rates according to expected spot rates (Irturk 2006). The liquidity premium theory states that an investor is indifferent between a long term investment and corresponding short term investments if they give the same return inclusive a liquidity premium. One can describe this theory with the same mathematical formula like in (4) but adding the liquidity or risk premium (Mishkin 2004):

$$i_{nt} = \frac{i_t + i_{t+1}^e + i_{t+2}^e + ... + i_{t+(n-1)}^e}{n} + l_{nt} \tag{5}$$

where l_{nt} is the liquidity (term or risk) premium for a n period bond at time t.

The big advantage of the liquidity preference theory is that "[…] the yield on longer-term bonds will […] reflect not only market expectations as outlined in the expectations theory, but also a risk (or 'liquidity') premium" (Pilbeam 2005: 89). In sum all of the three stylized facts on yield curve can be explained with this theory (Mishkin 2004) and for that reason it is very common in the literature.

Very close to the liquidity preference theory is the *preferred habitat theory*. This theory assumes, that investors have preferences on bonds with special maturity (preferred habitat) but are willing to buy also bonds of different type if this will be compensated by a premium (cf. ibid.). It is more or less a combination of market segmentation theory and expectation theory (Irturk 2006) but is not a direct development of it. In fact this theory comes to the same conclusions as the liquidity preference theory does (Mishkin 2004) and is therefore often used synonymously.
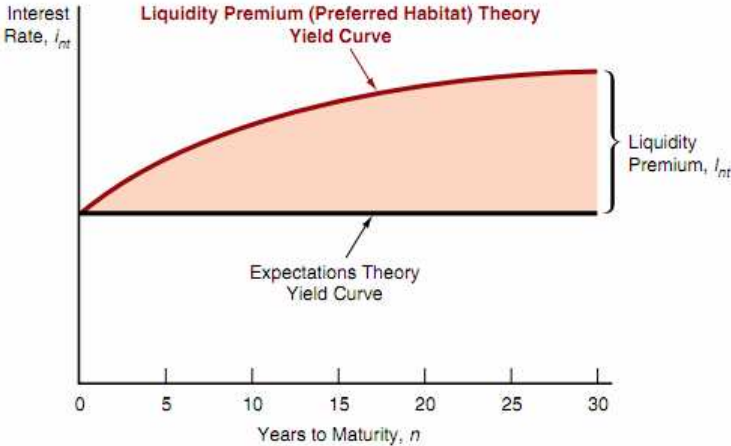

Figure 6 – Expectations and Liquidity Preference Theory Yield Curve
Source: Mishkin (2004: 134)

Figure 6 depicts the relationship between the expectations theory and liquidity preference theory yield curve graphically. The second is always above the first one, as the liquidity premium must be positive. This is because the compensation for higher risk is always a positive value. Empirical estimations have shown that for German bonds the risk premium lies between 0.14 percent for 3 month bonds and 1.5 percent for 10 year bonds (Wasmund 1999).

3.4 Testing the Expectations Theory

When expectations theory is true, the term structure of the yield curve – so the spread between long and short run yields – has a potential predictive power of future interest rate movements (cf. Campbell/Shiller 1991). For that reason there is a huge literature on testing the expectations theory, which results in mixed evidence of the applicability of the theory. In the next step this work should test the expectations theory with Austrian bond data before and after the beginning of the current crisis. The main question to answer is, if the potential predictive power of the yield curve is worse in the current crisis period.

The most common way to test the expectations theory is to regress the changes of future interest rates (or yields) onto the yield spread – which corresponds to the slope of the yield curve. These changes of future interest rates should be optimal forecasts. The first way to test whether the yield spread is an optimal forecast of interest rate changes is to test if the short run changes in the spread corresponds to changes in the long run yields (changes in long rates). One can do this econometrically via the following formula (such as equation (2) in Campbell/Shiller 1991: 497 and the regression of table 2 in Campbell 1995: 139):

$$y_{t+m}^{n-m} - y_t^n = \alpha + \beta\left(\frac{m}{n-m} y_t^n - y_t^m\right) + \varepsilon_t \qquad (6)$$

where y are the forward rates; n are the corresponding long term yields and m the short run yields.

When yield spreads give optimal forecasts of future interest rate movements, so that the expectations theory is true, the coefficient beta has to be equal to one. In the present empirical application with Austrian bond data the short term yields are of 6 month maturity (so m is always 6) – as they are the shortest one available.

sample 1 (04.01.1993 – 31.07.2007)

Δ in long rates	long run bonds (maturities)					
	12	18	24	48	60	120
	-0.5947**	-0.5849**	-0.5507**	-0.4831**	-0.3659**	0.0592
	(0.0202)	(0.0212)	(0.0244)	(0.0374)	(0.0427)	(0.0761)
R²	0.1929	0.1738	0.1237	0.0365	0.0199	0.0002
CS	-0.913	n.a.	-0.893	-1.447	-1.750	-3.198

sample 2 (01.08.2007 – 17.04.2012)[12]

Δ in long rates	long run bonds (maturities)					
	12	18	24	48	60	120
	-0.0046	-0.0411**	-0.0495**	-0.0609**	-0.0565*	-0.0551
	(0.0294)	(0.009)	(0.0118)	(0.0219)	(0.0268)	(0.0617)
R²	0.00	0.0175	0.0147	0.0066	0.0038	0.0007

Table 1 – Short run changes in long run yields
* are coefficients which are significant at the 5 % level, ** are coefficients which are significant at the 1 % level, rest is not significant, in brackets are standard errors; CS are corresponding Campbell/Shiller (1991: 502) results

In both samples one cannot find empirical evidence for the expectations theory as table 1 reports. The estimated coefficients are negative, so exactly the other way round as expected. The findings go ahead with those of Campbell/Shiller (1991) although the coefficients are not getting larger in the Austrian sample the higher the maturity of the bond is. The results of the crisis period are much lower compared to the previous sample and have a lower level of significance. In sum one could argue that the in crisis sample give worse results compared to the other, but that sample still gives incorrect results according to the hypothesis.

The second way to test the expectations theory is to forecast the long run changes in the short run yields (changes in the short rates). For that reason one has to regress the average of the short run yield spreads on the slope of the yield curve (long run yield minus short run yield). This procedure should be an optimal forecast of future short run yields and can be implemented econometrically by the following formula (such as equation (3) in Campbell/Shiller 1991: 497 and the regression of table 2 in Campbell 1995: 139):

$$\frac{1}{n-m}\sum_{i=1}^{n-m} y_{t+i}^m - y_t^m = \alpha + \beta\left(y_t^n - y_t^m\right) + \varepsilon_t \qquad (7)$$

where y are the forward rates; n are the corresponding long term yields and m the short run yields.

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[12] The split of the sample is due to this dates, as the beginning of the financial crisis is dated by August 2007; see http://www.investopedia.com/articles/economics/09/financial-crisis-review.asp#axzz2BY2SZ9ZV (14.11.2012)

Also in that estimation m is always 6 months and the coefficient beta should be one according to expectations theory. The results for Austrian data before and within the current crisis are reported in table 2.

sample 1 (04.01.1993 – 31.07.2007)

Δ in short rates	long run bonds (maturities)					
	12	18	24	48	60	120
	0.3139	0.2272	0.1892	0.1077	0.0908	0.1136
	(0.0137)	(0.0069)	(0.0059)	(0.0052)	(0.0052)	(0.0065)
R²	0.1256	0.2283	0.2200	0.1064	0.0892	0.0791
CS	0.044	n.a.	0.186	0.942	1.242	1.228

sample 2 (01.08.2007 – 17.04.2012)

Δ in short rates	long run bonds (maturities)					
	12	18	24	48	60	120
	0.872	0.9092	0.9373	0.9058	0.8814	0.8208
	(0.0153)	(0.0125)	(0.0108)	(0.0105)	(0.0112)	(0.0129)
R²	0.7333	0.8200	0.8656	0.8673	0.8460	0.7918

Table 2 – Long run changes in short run yields
all the coefficients are significant at 1 % level, in brackets are standard errors; CS are corresponding
Campbell/Shiller (1991: 504) results

Table 2 shows that the coefficients are – as expected – positive now. For the sample before the crisis the evidence for the assumption of the thesis is very poor. Except for longer maturities than 48 months the coefficients correspond to those the Campbell/Shiller (1991) approach. As the estimated coefficients of wider spreads are closer to one, they argue that they have found evidence for the expectations theory. Interestingly the sample for Austrian bonds during the crisis gives a higher evidence for the truth of expectations theory than the sample before. Nearly every coefficient is near by one with a very high R². In sum one can argue that the data during crisis gives more evidence for expectations hypothesis than the other sample. There is evidence against the main idea of a negative influence of the current crisis on testing the expectations theory.

As has been explained in the theoretical part above, "[…] the interest rate risk premium is not irrelevant […]" (Leite et al. 2010: 109), the (pure) expectations theory may never be explored throughout data. Nevertheless the results above offer some evidence for the rationality of financial market agents. The estimates of the short run changes in the yield of longer bonds give almost always a forecast in the wrong direction, whereas the long run changes in the short rates result in correct forecasts. This (Campbell-Shiller) paradox may be caused by different possible reasons (Thornton 2003): The risk premium is not constant but time varying, long term rates may lead to an overreaction in financial markets on expected changes in short run yields, market participants are not able to predict policy changes in short run rates,

rational expectations may be variable over time and more. Until now there is no mainstream solution of this problem, although Thornton wanted to give an econometrical solution of it.

3.5 Yield Curve modeling

As one cannot observe the yield curve (in its continuous form) directly in the market, but just the spot rate of bonds for each maturity, this section deals with methods how to model and estimate a continuously compounded curve.

During the last three centuries much effort has been put into the modelling and econometric estimation of forward rates and therefore yield curves (Diebold/Li 2003). Two major traces developed in that process, the approach of modelling the term structure by no-arbitrage models and the one with equilibrium models. No-arbitrage models focus on the perfect fitting of the term structure without any arbitrage possibilities whereas equilibrium models put more weight on dynamic aspects of the modelling, which are also called affine models (ibid.).

At the end of the 80s Nelson and Siegel introduced a new framework, out of the traditional no-arbitrage and equilibrium approach. They created a three-parameter (non-linear) exponential function model which was further developed by Svensson. As this approach has become more and more mainstream and many central banks like the German Bundesbank uses this method of modelling the yield curve (Deutsche Bundesbank 1997), we want to focus on describing the Nelson/Siegel and Svensson framework a little bit more in detail.

The goal of Nelson and Siegel was to find a model that fits to the typical pathway of the yield curve (Schich 1997) described by the stylized facts and also by the possible shapes of the yield curve like above. The idea they had was to fit the term structure from the solution of a differential equation of the forward rates (Nelson/Siegel 1987). The forward rates should be approximated by a three-component exponential differential equation. The model for this approximation looks like the following (ibid.):

$$f_t(\tau) = \beta_1 + \beta_2 e^{-\lambda_t \tau} + \beta_3 \lambda_t \tau e^{-\lambda_t \tau}$$

where τ is the maturity of the bond and β_1, β_2, β_3 and λ are parameters.

By dividing with the maturity m and adding a Laguerre function one gets the approximation of the exponential decay term function of the yield curve (for more details see Nelson/Siegel 1987):

$$y_t(\tau) = \beta_1 + \beta_2 \frac{1-e^{-\lambda_t\tau}}{\lambda_t\tau} + \beta_3 \left(\frac{1-e^{-\lambda_t\tau}}{\lambda_t\tau} - e^{-\lambda_t\tau} \right) \qquad (8)$$

$$\lim_{\tau\to\infty} y_t(\tau) \to \beta_1 \qquad\qquad \lim_{\tau\to 0} y_t(\tau) \to \beta_1 + \beta_2$$

In this approximation the β_1 parameter is a constant and can be seen as the long term interest rate, when the maturity goes to infinity (Schich 1997). The longer the time to maturity the more the interest rates move together (see fact 1). At the beginning of a bond period, when maturity converges to zero, this function goes to $\beta_1 + \beta_2$, which can be interpreted as the very short term interest rate (ibid.). The parameter λ is a time constant and determines the rate at which the regression variable decays to zero (Nelson/Siegel 1987). It has to be calibrated in the estimation process.

Let's first have a closer look to the extension of that model made by Svensson and then further interpret it. Svensson developed the initial model by adding a supplementary term with two new parameters. Therefore he enriches the flexibility of the approximation (Schich 1997). The developed approximation looks as follows – with the same limit assumptions (Svensson 1994):

$$y_t(\tau) = \beta_1 + \beta_2 \frac{1-e^{-\lambda_t\tau_1}}{\lambda_t\tau_1} + \beta_3 \left(\frac{1-e^{-\lambda_t\tau_1}}{\lambda_t\tau_1} - e^{-\lambda_t\tau_1} \right) + \beta_4 \left(\frac{1-e^{-\lambda_t\tau_2}}{\lambda_t\tau_2} - e^{-\lambda_t\tau_2} \right) \qquad (9)$$

The first term of this model describes the long term yield level. The second term is a monotonic decreasing function which describes the time to settlement, the decay to zero. It could also be increasing if the parameter β_1 is negative. The third and fourth term depict an approximation of the hump shape (or U-shape if the parameter is negative) of the yield curve (ibid.). Diebold/Li (2003) interpret the first term as the yield curve level, the second as the yield curve slope and the third one as its curvature.

By looking at a graph of the components of the Nelson/Siegel model, one can see that it gives quite a good approximation of the behavior of yield curves.
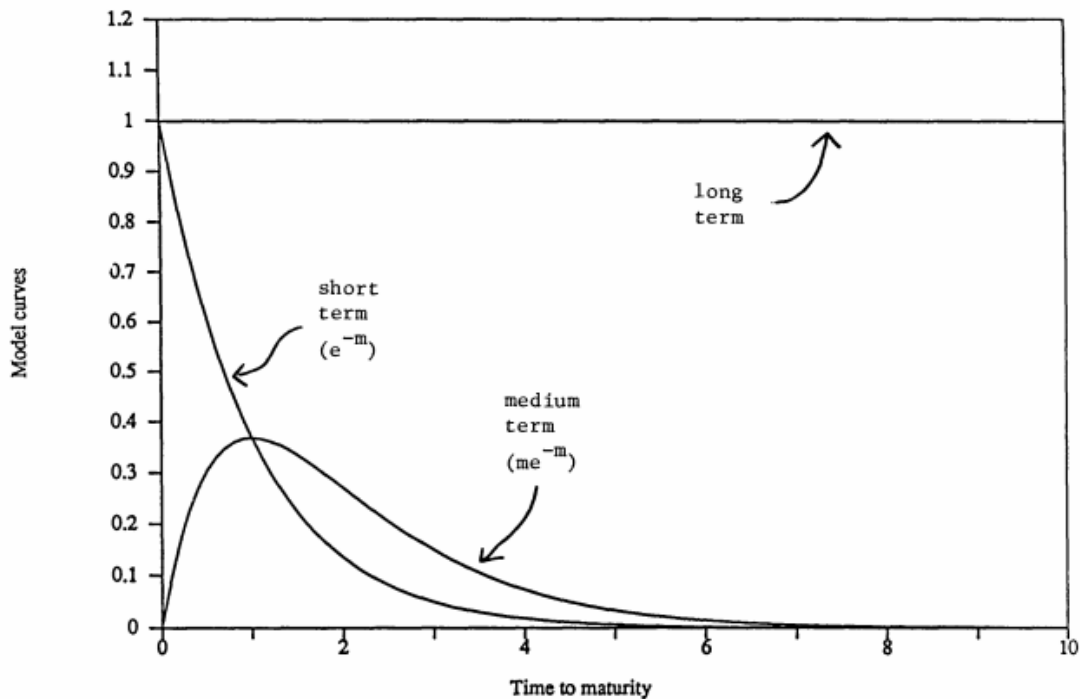
Figure 7 – Components of Nelson/Siegel yield curve approximation
Source: Nelson/Siegel (1987: 477)

If data for the daily yield of bonds are available, one can estimate the parameters of (8) and (9) and calibrate λ. For a more detailed description of that estimation see Schich (1997: 17 et seq.).

These two methods of modelling the yield curve are nowadays quite standard and used (as mentioned above) by central banks. The Svensson estimation results in better statistical properties and is – as widely used – internationally well comparable (Deutsche Bundesbank 1997). Due to its simplicity the Nelson/Siegel approach is also commonly used for modelling different aspects of the yield curve.

As we understand what yield curves are, what form and behavior they can have, under what corresponding theoretical approach they can be seen and how to model a yield curve out of observed data, we now turn to the question what economic interpretations can be derived from them. What lessons can be drawn by analysing the yield curve will be part of the next chapter, which is interesting for policy makers as well as for investors. The answer of this entire question will be given with respect to the main question of this work: are there any dif-ferences according to current financial and debt crisis?

4 What to learn from the Yield Curve

Just understanding how the yield curve is created and what different forms it can have, is not as interesting as knowing what this various forms can tell us. In this chapter we want to explore what (possible) lessons one can draw from the term structure of interest rates. If an investor does not know what implications e.g. a hump shaped yield curve has, he may make a wrong decision. The same is true for economic and monetary policymakers.

In economics the field of predicting future economic activities, e.g. expected unemployment rates, GDP growth and many more, is a very wide one. This is because of its great practical importance, but doing this well is not an easy task. Models which want to predict future activities or developments are laden with many assumptions and uncertainties so that it is impossible to predict the future exactly. Therefore indicators, which can reflect expectations, are very important for researchers. The yield curve[13] therefore can be one tool for depicting expectations from the (financial) market. The information the yield curve contains, can be used for getting a clearer view of how financial markets expect future developments due to interest rates, inflation, risk premium and real output (Berk 1998). The latter may be also very useful for monetary policy purposes (ibid.). Extracting information of future movements from those economic variables is sometimes very complicated and needs sophisticated (macro) models (Joyce et al. 2010). Let's have a closer look at the different informational contents the yield curve can give and answer the question of a possible change in that contents during the crisis

4.1 Inflation and risk premia

From the expectations theory we know that if there will be higher inflation rates in the upcoming periods, investors want to have compensation in the form of higher interest rates and therefore yields. The longer an investment is the higher the risk premium normally is, as the uncertainty for the investor increases. If one combines these facts with the preferred habitat theory the following expression for the yield of a bond at time t – which lasts for m periods – can be defined (from Berk 1998):

$$y_t^m = E_t r_t^m + E_t \pi_t^m + \phi_t^m$$

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[13] As mentioned above, the yield curves of government bonds are the most important for the economy – as also linked with monetary policy. For that reason this kind of yield curve is meant by talking about "the" yield curve.

where E is the expectations operator, r is the real interest rate of a m period bond at time t, π is the inflation and ɸ is the average risk premium.

As well as this theoretical relationship may cause identification problems, as those three factors are not perfectly correlated (Berk 1998), the empirical findings are also not that clear.

Chadha/Holly (2010) found from US and UK data that there is a statistically significant correlation between the yield spread (long term yield minus short term yield) and inflation. This correlation is negative, as expected from the formula above. When the yield spread is increasing, market expect a higher short term interest rate (see expectations theory). To balance the equation above, the inflation rate has to decrease. According to the authors the yield curve gives better information of future inflation by considering the first two quarters ahead.

Campbell and Shiller have shown that for US data the hypothesis of predicting future inflation by yield curve data can be rejected quite easily, whereas Fama got some empirical evidence with respect to expected inflation and risk premia but had problems to isolate those effects (Berk 1998).

Joyce et al. (2010) used a joint model, which is based on a so called essentially affine model of the term structure,[14] to extract the expected inflation and risk premia from the yield curve. To do so they model the dynamics of inflation expectations as a function of the information the yield curve gives according interest rates. In their econometric implementation they use a Vector Autoregression (VAR) to include all relevant relations into one regression. For filtering and testing the effects they use restricted regressions afterwards. For UK data the authors find a link between yield curve data and inflation expectations and risk premia. They also found that long term risk premia and inflation expectations have been lower since the Bank of England acts as an independent player.

A model which should describe the dynamics of the change in inflation expectations through a DSGE model has been made by Estrella (2004). He combined the IS equation, the Phillips curve and the term structure into a macroeconomic model. Implicitly the author integrated the monetary policy rule with an inflation target into his model. Simulations of the model for US data have shown that the yield curve spread can be taken as a predictor for inflation, but there are variations according post 1987 area and before. This results because before 1987 Volcker has been the chairman of the Fed with different appointments of monetary policy than Greenspan afterwards. Estrella concludes that there is no structural relationship be-

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[14] There are two main approaches in the literature, the essentially affine models and the macro-linked models. First are structural models, whose dynamics are modelled as a function of an informational vector (see Duffee 2002). Second are dynamic stochastic general equilibrium models (DSGE) which are linked to real business cycle models (RBC) or New Keynesian models.

tween yield curve data and inflation expectations, but for flexible or strict monetary policy regimes the predicting power of his model corresponds to previous affine model results.

The study by Doh (2012) goes in a similar direction. He argues that the yield curve can tell something about the implicit inflation target of a central bank. This is because the long term inflation expectations – which are driven by monetary policy targets – affects also long term interest rates. The model the author used in his approach was a New Keynesian model where firms refer to sticky prices due to monopolistic structures and households maximizes their lifetime utility. For US data the hypothesis that the yield structure is determined by the inflation target of the Fed cannot be rejected. Doh further noticed that market participants learn changes in the inflation targeting more quickly in contrast to other studies.

One can also split the impact of monetary policy and inflation on the slope of the yield curve into the different eras of central bank chairmen. The Fed policy for example has a lower association with changes in the yield curve slope during the era of Greenspan than in previous times in history (Gamber/Joutz 2005). For changes in short term rates the relationship with changes in the yield curve slope is also negative in Greenspan era, but less pronounced than in other chairmen periods (ibid.).

The empirics about the ability of the yield curve to predict inflation movements are not quite clear. Berk (1998: 312) concludes: "In sum, our review of the literature on the information content of the yield curve leads us to conclude that the empirical relationship between the yield curve and expected future inflation is complicated, and specific for a particular segment of the yield curve studied, as well as for the specific periods and countries analysed."

The varying slope of the yield curve reflects also the weakness of simpler models, which assumes a constant risk premium. More sophisticated models of the yield curve want to estimate risk premia as time-varying variables (Wasmund 1999). This is caused by the interbank market as banks are not willing to lend long term money without a premium and this has to be time-variable to insure against short run interest rate fluctuations. To model this risk premia one can use an ARCH model (autoregressive conditional heteroscedasticity). For German data this gives a holding risk premium estimation of 0.13 for a 3 month bond and goes up to 1.5 for 120 months (ibid.).

As there is no standard or mainstream model and the empirical results are that unclear, no empirical study with Austrian yield data will be done here.

4.2 Future economic activity

There is a wide discussion in literature, if the yield curve gives information about the upcoming economic development. Considering a standard IS-LM model, one can conclude that in an up swinging economic situation, interest rates – short but also long term ones – will rise. This is caused by an increase of money demand in expansionary times and therefore boosts the price of money which will be reflected through interest rates. If we assume sticky prices[15] in the presence of a real economic shock, a positive yield spread indicates a future economic upswing – a negative yield spread indicates an economic slowdown as interest rates are expected to decline (Berk 1998). The impact on the yields due to changes in the (short-term) interest rate can be explained by the policy anticipation hypothesis. It says, when monetary policymakers are reducing the interest rate during recessions, this will also affect other (financial) market participants in the way that they expect lower interest rates when they expect an economic downswing. So "[t]he yield curve picks up the financial market's estimate of future policy" (Haubrich/Combrosky 1996: 27).

A positive shock will shift the IS-curve to a higher output level and with the assumption of not adjusting prices the economy will end up also with higher interest rates. The behavior of the yield curve is therefore changing across the business cycle. During recessions the term premia on long term bonds are high, those of short term bonds are low. As long term bonds have higher yields, the yield spread during a recession is positive, this is also driven by the unwillingness of investors to take risks in uncertain times (Ang et al. 2004). In booming periods long term yields tend to be lower than short term yields as – mentioned above – the demand for money increases. Short term yields are therefore procyclical according to the business cycle. This effect is caused by national banks that take actions through monetary policy tools to stimulate or slowdown the economy which has a direct influence on short term rates (ibid.).

Most of the empirical studies on that issue came to the conclusion that the yield curve is positively related to an economic upswing. Ang et al. (2004) specified a model that should have a predictive power of the whole yield curve, not only the long term spread like most of the other models, with respect to long term GDP growth. Simulations with US data have shown that high short rates cause a lower GDP growth (ibid.). The DSGE model of Estrella (2004) above not only came to the conclusion that the yield spread has a positive relationship with inflation, but also concluded that there is an empirical evidence for a positive relation between the yield spread and the prediction of output.

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[15] With instantaneously adjusting prices the relationship is not that clear.

The empirical evidence for the predictive power of the yield curve for economic growth is that strong that some authors pointed out the extra power of the yield curve with respect to other leading indicators (Berk 1998). In sum one can conclude by studying literature: "During recessions, upward sloping yield curves not only indicate bad times today, but better times tomorrow" (Ang et al. 2004: 2), which is also true the other way round.

As the yield curve should influence or predict future economic activity, one can plot the yield spread together with the GDP growth rates to get a first graphical impression. GDP growth rates are one of the most common indicators for economic up- or downswings. The yield spread should approximate the slope of the yield curve. One can choose a very short spread, e.g. the yield of a bond with 12 month maturity minus the yield with 6 month maturity, or long spreads (yield with longer maturity minus short term maturity yields). In literature the focus is on longer term spreads (cf. Haubrich/Dombrosky 1996) and so do we here. Positive yield spreads should be correlated with future GDP growth rates. To simulate this, one can plot the growth rates lagged for some quarters.

In the appendix one can see a plot of the GDP growth rates for Austria from 1993 quarter 1 to 2012 quarter 1 taken from OECD statistics together with the long term yield spreads from Austrian bonds lagged by 4 quarters. The yield spreads in this case are 28 quarters ahead, so the difference of 90 month yields and 6 month yields[16] has been taken. Because yield data is on daily basis, it was necessary to take the average of the spreads for each quarter – as also Haubrich/Dombrosky (1996) did.

By having a look at that graph it can be seen that most of the recessions and boosts in the GDP growth line go in the same direction as the yield spread curve. One could conclude through this plot that the long term yield spread is a good indicator for GDP development. Zooming in the plot of 2007 Q3 to 2012 Q1 gives the same result, as can be also seen in the appendix.

According graphical analysis one could argue that the yield curve has not lost its predictive power in the current financial and debt crisis. But doing just a graphical (qualitative) analysis is of course not a very convenient way to draw conclusion according the predictive power of the yield curve as an indicator for future economic activities. A quantitative method is therefore necessary.

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[16] 6 month is the shortest rate in current dataset

A common way in literature is to test a simple model which explores the impact of the yield spread on GDP growth. For this reason the following model – which corresponds to Ang et al. (2004) – will be applied to Austrian data. GDP growth rate data from OECD statistics on quarterly basis are regressed on the yield spread of different maturities:

$$g_{t+k} = \alpha_k^m + \beta_k^m \left[\frac{1}{N} \sum_{i=1}^{N} \left(y_{ti}^n - y_{ti}^6 \right) \right] + \varepsilon_{t+k}^m \qquad (10)$$

where k is the number of lags (in quarters), m is the spread maturity (in quarters) and N the number of observations per quarter. For each quarter the average of the yield spreads has to be computed, like in Haubrich/Dombrosky (1996) mentioned above.

To forecast the future development of GDP growth rates, one can use the estimated coefficients and implement it into a simple autoregressive model with given yield spread data. There are also other models additional to this simple yield spread model. Some models include leading indicators and yield curve data to predict future output (see ibid.). This work uses the yield spread model, because most authors are focusing on the yield spread to predict GDP growth (Ang et al. 2004) and because the in-sample and out-of-sample forecasts in this model have the lowest root mean squared errors (RMSE) compared to other models (Haubrich/Dombrosky 1996).

In the next step not the whole forecasting procedure should be simulated with Austrian data, but just the fit of the yield spread model should be explored. The question of a possible worse fit caused by the crisis should be answered by splitting the sample in data before the crisis and after it. As the range of the sample after or during the current crisis is (with quarterly data) very small, the effect should be isolated by comparing the results of the sample from 1993 Q1 to 2007 Q3 (before crisis) and the full sample. Literature is focusing mostly on wide yield spread maturities. For Ang et al. (1996) the whole yield curve has a positive influence on GDP growth, for this reason this work also include estimates of some different spread maturities.

Regressing the quarterly GDP growth on the yield spread – like in (10) – for the sample before the crisis the following results are obtained within Austrian data:
As can be seen in table 3 most of the estimated coefficients are positive except the 4 quarter lagged. Especially those of lower lagged horizons are statistically insignificant. The R² of those coefficients is very small, so the variation of the model cannot be explained well through the model itself. For larger lagging horizons and wider spread maturities the (posi-

tive) statistical impact of yield spreads on GDP growth is getting more significant. Those co-efficients have higher statistical significance (at least on 5 % levels) and also the total variation can be explained at a higher percentage throughout the model.

Horizon k-qtr ahead	Yield spread maturity (in quarters)					
	2	8	16	20	24	28
	β_k^2	β_k^8	β_k^{16}	β_k^{20}	β_k^{24}	β_k^{28}
1	**0.2052**	**0.0497**	**0.033**	**0.0277**	**0.0238**	**0.0206**
	0.3189	0.1209	0.0826	0.0744	0.0697	0.0669
	R^2=0.0073	R^2=0.0030	R^2=0.0028	R^2=0.0025	R^2=0.0021	R^2=0.0017
4	**-0.0029**	**-0.0589**	**-0.025**	**-0.0108**	**-0.00008**	**0.0082**
	0.3267	0.1241	0.0867	0.0788	0.0743	0.07172
	R^2=0.000	R^2=0.0042	R^2=0.0016	R^2=0.0004	R^2=0.0000	R^2=0.0002
8	**0.1931**	**0.1144**	**0.1203**	**0.1212**	**0.124**	**0.1273**
	0.3238	0.1215	0.0847	0.0769	0.0726	0.07
	R^2=0.0072	R^2=0.0178	R^2=0.0396	R^2=0.0482	R^2=0.0562	R^2=0.0631
12	**-0.1067**	**0.127**	**0.1663**	**0.1676***	**0.1685***	**0.1683***
	0.3307	0.1235	0.0848	0.0767	0.0712	0.0696
	R^2=0.0023	R^2=0.023	R^2=0.0788	R^2=0.0959	R^2=0.1081	R^2=0.1151

Table 3 – Effect of yield spread on GDP growth before crisis
sample = 1993 Q1 to 2007 Q3
2nd row of each estimation gives the standard errors, * are coefficients which are significant at 5 %

Positive coefficients around 0.1 to 0.2 with a R² of circa 10 % do of course not verify the relationship, but one can argue that the higher the yield spread maturity and the lagging horizon is, the higher the statistical significance of a positive effect of yield spreads on GDP growth is. This result is not consistent with the findings of Ang et al. (2004), who did the estimation for US data. They found that the 1 and 4 year lagging horizons have the highest predicting power for future output activity. The results vary with different term spreads, which is in contrast to the findings of this work. This may result because Ang et al. took 1 month yield data to compute the yield spread, whereas this work can just revert to 6 month yields for the short term usage.

Doing the same exercise for the full sample one can see the impact of the current crisis (and its policy measurements) on the yield spread and GDP growth relationship.

Horizon k-qtr ahead	Yield spread maturity (in quarters)					
	2	8	16	20	24	28
	β_k^2	β_k^8	β_k^{16}	β_k^{20}	β_k^{24}	β_k^{28}
1	**0.081**	**0.076**	**0.089**	**0.0852**	**0.0804**	**0.0752**
	0.29	0.149	0.0999	0.089	0.0826	0.0784
	R^2=0.001	R^2=0.0035	R^2=0.0106	R^2=0.0122	R^2=0.0127	R^2=0.0123
4	**0.0387**	**0.1079**	**0.1319**	**0.1329**	**0.1327**	**0.1318**
	0.4232	0.1594	0.1034	0.092	0.0845	0.08
	R^2=0.0001	R^2=0.0064	R^2=0.0224	R^2=0.0287	R^2=0.0335	R^2=0.0368
8	**-0.0097**	**0.1428**	**0.1725**	**0.1727**	**0.1731***	**0.1733***
	0.4387	0.1615	0.1051	0.0932	0.086	0.0817
	R^2=0.0000	R^2=0.115	R^2=0.0387	R^2=0.0487	R^2=0.0569	R^2=0.0629
12	**-0.241***	**0.1645**	**0.211***	**0.2077***	**0.2038***	**0.1996***
	0.471	0.1747	0.1144	0.1018	0.0946	0.09
	R^2=0.0041	R^2=0.0139	R^2=0.0515	R^2=0.0619	R^2=0.0686	R^2=0.0719

Table 4 – Effect of yield spread on GDP growth on full sample
sample = 1993 Q1 to 2012 Q1
2nd row of each estimation gives the standard errors, * are coefficients which are significant at 5 %

The results in table 4 show that most of the coefficients are positive, which correspond to a positive effect of the yield spread on GDP growth. As in the estimations above, the coefficients are getting more significant the higher the lagged horizon and the wider the yield spreads are. The size of the estimated coefficients is a little bit higher in the full sample, which could be caused by a higher number of observations. In fact one can say that the effect in both estimated samples goes in the same direction.

Comparing both regressions graphically, one can see that there is a corresponding positive effect of the yield spread on GDP growth in both samples. The scatter plots in figure 8 show a weaker positive correlation in the sample before the crisis. For the full sample the positive effect is higher, which is expected by this model. That means also that the current financial and debt crisis has no negative effect on the expected outcomes of the estimated model.
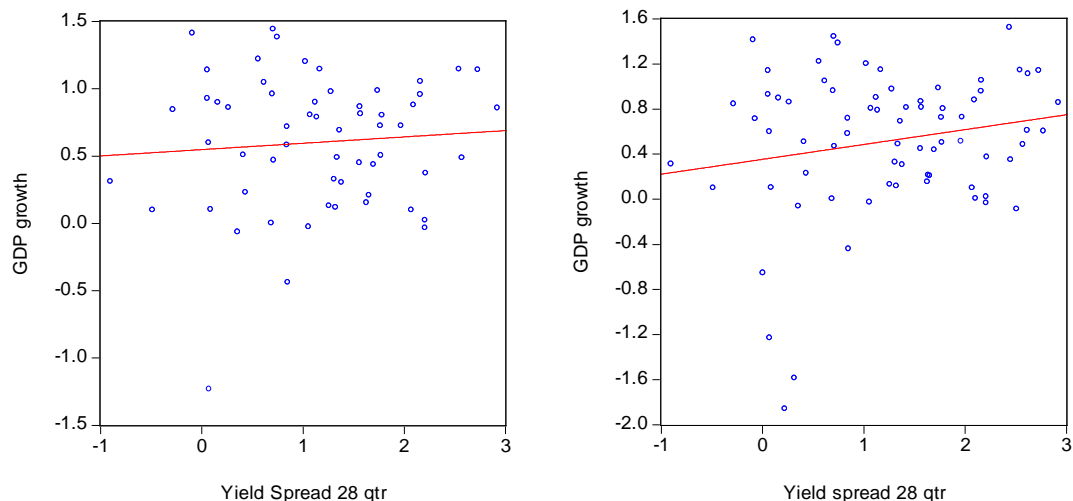
Figure 8 – Scatter Plot: effect of the yield spread on GDP growth
sample 1993 Q1 – 2007 Q3 (left), full sample (right); both lagged by 4 quarters

From the analysis above one cannot find high statistical support for the assumption of a negative effect on the predictive power of yield data caused by the current crisis for Austrian data. The results of the estimations in both sample groups are of the same direction, the results have even a little higher statistical significance by including the data of the actual crisis.

4.3 Implications for monetary policy makers

The information central banks can use from yield curves is split into two parts. On the one hand the information the slope of yield curves can give for central banks is useful, as they can control and influence the short term interest rate via monetary contractions or expansions. On the other hand not the whole yield curve gives appropriate information because long term yields are not directly controllable for monetary authorities (Berk 1998). The relationship between inflation changes and the yield curve is not that clear, which has been shown above, as the relationship between the curve's information about future economic activity. So central banks might not use the yield curve as a (single) information variable for monetary policy purposes (ibid.), if one defines price stability and control of inflation as their main target.

Beside the informational content due to inflation, risk premia and the GDP movement the yield curve may also contain information about future yield developments. How this works is part of the next chapter, but beforehand we want to explore possible impacts of knowing the future path of interest rates for the government.

When the shape of the yield curve is upward sloping, the short term yield is lower than the long term yield, but short term ones are expected to increase due to expectations theory. The

other way round for a downward sloping yield curve (inverted slope). One can think that during periods of upward sloping yields the government should shorten the maturity of their new issued debt securities, as short term interest rates are low. Exactly this kind of thinking the Clinton administration had in the early 1990s (Campbell 1995). They shifted more than $ 50 billion from long run to short run – 2 to 3 years – Treasury bills, which was a dramatic change in the US debt policy (ibid.). The question nevertheless is if short term borrowing is really cheaper? To answer this question one has to prove the expectations theory – which was done in the previous section. But Campbell (1995) cannot see any clear evidence that short term borrowing is cheaper. Only if the government has superior information about future developments of interest rates shortening the debt could be advantageous. As in most of the highly industrialised countries the central banks are independent, this is not quite realistic. According to the risk of short term borrowing one has also to distinguish between nominal and real interest rates. As inflation movements are not clear in long run, issuing just short term debts instruments might not be that optimal (ibid.). All in all the way how to make debt management with interest rate expectations caused by the yield curve is not that clear.

4.4 Forecasting the interest rate

One of the most important and interesting questions for policymakers and strategic investors, is to have an idea of the development of interest rates. If one knows the future interest rate or implicitly the yield of an investment, one can make more appropriate decisions now. The path of the yield of government bonds is also important for fiscal policymakers, as have been shown above. For that reason this chapter explores how to predict the interest rate, i.e. the yield of government bonds, especially with the term structure of the yield curve. After explaining the main models how to do this, an empirical study of the predictive power for data before and since the crisis will be done.

Like in modelling and fitting the yield curve itself, there are also several possibilities to generate a model that predicts the future yield curve levels. Within affine and quasi-affine models one can forecast the future yield curve development by putting the yield curve structure into a model with no-arbitrage conditions (Matsumura et al. 2010). Most models have a direct or indirect link to the yield curve and/or term structure, but there are also models which want to forecast the yield curve path with different macroeconomic variables. For example Mönch (2005) created a model just with macro variables that should give a better interpretation of changes in the yield curve due to (macro-) economic developments. Therefore he introduced a huge number of variables that should explain the yield curve structure, i.e. he models more than 30 employment variables, 30 price indices, output gap, inflation etc. (ibid.). General AR and VAR models describe the yield curve path just by modelling the lagged yields (Matsu-

mura et al. 2010). Another approach is a model that takes the Nelson-Siegel idea in a more sophisticated way to forecast future yield levels. As this model, by Diebold and Li, is superior in most out-of-sample predictions (Yu/Zivot 2011), it should be explained here in detail, as it will also be the basic model of the ongoing empirical research.

4.4.1 The Diebold-Li Model

Diebold/Li (2003)[17] use the Nelson-Siegel approach to describe the behavior of the yield curve in a three-factor model. To forecast the future yields they use a two-stage procedure. First of all one has to find the in-sample fit throughout the Nelson-Siegel three component model like in (8). The goal is to estimate the three latent factors, not as fixed coefficients, but in a dynamic process. Diebold-Li assume that these factors vary each period, e.g. each day if one considers daily data or each month within monthly data. The decay rate λ_t is assumed to be fixed at a certain level for each t. By applying OLS regressions to (8) for each t one gets a time series of estimated factors

$$
\begin{bmatrix}
\hat{\beta}_{11} & \hat{\beta}_{21} & \hat{\beta}_{31} \\
\hat{\beta}_{12} & \hat{\beta}_{22} & \hat{\beta}_{32} \\
& ... & \\
\hat{\beta}_{1T} & \hat{\beta}_{2T} & \hat{\beta}_{3T}
\end{bmatrix}
= \begin{bmatrix} \hat{\beta}_{1t}, & \hat{\beta}_{2t}, & \hat{\beta}_{3t} \end{bmatrix}
$$

To forecast the future yield level the second step of the Diebold-Li procedure is to predict these estimated factors and re-put it into the Nelson-Siegel framework. Diebold-Li forecast the beta factors by an underlying autoregressive process of order one and by a multivariate vector autoregressive process of order one. As the results of the AR(1) process have a higher predictive power, we just describe this procedure.

In the AR(1) process the factors are predicted by the following specification:

$$
\hat{\beta}_{i,t+h/t} = \hat{c}_i + \hat{\gamma}_i \hat{\beta}_{it} \qquad i = 1, 2, 3 \tag{11}
$$

The coefficient c and gamma are obtained by the following regression:

$$
\hat{\beta}_{it} = c_i + \gamma_i \hat{\beta}_{i,t-h} \qquad i = 1, 2, 3
$$

where h is the forecasting horizon (e.g. 1 month, 14 days etc. depending on the data used)

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[17] further Diebold-Li

Given the predicted factors in (11) the predicted term structure of the yields is formed by re-filling it into (8):

$$\hat{y}_{t+h/t}(\tau) = \hat{\beta}_{1,t+h/t} + \hat{\beta}_{2,t+h/t}\frac{1-e^{-\lambda\tau}}{\lambda\tau} + \hat{\beta}_{3,t+h/t}\left(\frac{1-e^{-\lambda\tau}}{\lambda\tau} - e^{-\lambda\tau}\right) \qquad (12)$$

where h is again the forecasting horizon.

Diebold-Li evaluated their out-of-sample performance with results from other models and came to the conclusion that their simple AR(1) model has the highest predictive power with respect to the RMSE as the performance criterion. There has also been a broad work on extending the Diebold-Li model to make even more accurate forecasts. Bernadell et al. (2005) created a "regime-switching expansion" of the Diebold-Li model, by adding some economic variables (like GDP or inflation) to the common model, but also including macro variables does not improve the predictive power (Matsumura et al. 2010). All in all it seems to be the mainstream conclusion that, "[t]he simple two-step AR(1) method of DL is still the most accurate forecasting model" (Yu/Zivot 2011: 3).

An empirical analysis with the explained Diebold-Li method should be done now with Austrian yield curve data. The question of possible different predictive powers between pre and post crisis data is the main challenge and is due to the idea that financial markets do not behave in the normal, rational way caused by higher uncertainty and so on. For that reason the sample is split into two (ranges), the first sample includes data before the crisis until July 2007. As the data is on a daily basis, it has to be split by exact days. The sample goes from 4.1.1993 to 31.07.2007 where the range from 20.6.2007 to 31.07.2007 is taken to test the out-of-sample performance. The second sample is that one after and during the current crisis and goes from 1.8.2007 to 17.4.2012 and from 5.3.2012 to 17.4.2012 as the out-of-sample range. The Diebold-Li approach operates with data on a monthly basis (end-of-month data) and therefore the forecasts refer to months. As the fit of the yield curve can of course also be done with daily data, this study works with daily data. This should be done also to make the range of the second sample wider and therefore enhance the statistical significance because of more observations.

The forecasting horizon should be one, seven, fourteen and thirty days, so the h = 1, 7, 14, 30. The corresponding maturities of the bonds are τ = 6, 12, 30, 90. The λ is fixed at 0.077 for each t, equally to Yu/Zivot (2011).

To work with time series, i.e. with an AR(1) process, it is important not to have problems with non-stationary data. The Augmented Dickey-Fuller test suggests that the first estimated factor coefficient from (8) $\hat{\beta}_{1t}$ may have unit root for the first sample but not for the second sample. The factors $\hat{\beta}_{2t}$ and $\hat{\beta}_{3t}$ have no problems with non-stationarity according to the Augmented Dickey-Fuller test. One gets the same results by applying the Phillips-Perron test, a graphical view of both samples can be seen in the appendix. The pairwise correlations between these estimated coefficients are very small. From the Partial Autocorrelation function (PACF) one can conclude, that applying an AR(1) process might not cause any problems, which can be also seen in the appendix.

After the Diebold-Li two step procedure, so forecasting the loading factors in (11) and out of this calculating the predicted yield levels (12), one has to compare the fit of both samples. One common way to do this is to compare the calculated root mean squared errors (RMSE)[18] like Diebold-Li and also Yu/Zivot (2011) did. The RMSE as a criterion of the out-of-sample fit measures the difference between the actual and the predicted value. The results for Austrian government bonds for both samples are reported in table 5.

One can see, that in both samples the RMSE are getting large the larger the forecasting horizon is, as one would expect. The behavior of RMSE according to the various maturities is a little bit different than in Diebold-Li results. They found low RMSEs within the lowest maturity, for higher τ it is getting higher and within the highest maturity the RMSE is getting lower again. The RMSEs of the Austrian data are different in the way, that for the lowest maturity (6 months) the values are higher than for all other maturities. This is quite an interesting observation, which implies that for Austrian yield data the long term bonds have a higher predictive power for future yield level developments than those with a shorter maturity.

Comparing the two observed samples it can be seen that the RMSEs of the second sample (the sample during the crisis) are higher that those of the first one. Although the behavior due to the maturity is the same in both samples, so forecasts for longer term yields have lower root mean squared errors. The predictive power of the Diebold-Li procedure in the second sample is therefore lower compared to the sample before the crisis. Higher uncertainty in the financial markets might be a reason for the worse ability to forecast the future path of government bond yields out of the yield curve structure.

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[18] $RMSE = \sqrt{\dfrac{1}{n}\sum_{i=1}^{n}\left(y_i(\tau) - \hat{y}_i(\tau)\right)^2}$

1 day ahead

maturity (τ)	sample1 RMSE	sample2 RMSE
6	0.0384	0.5551
12	0.0022	0.3247
30	0.0018	0.2804
90	0.0465	0.1905

7 days ahead

maturity (τ)	sample1 RMSE	sample2 RMSE
6	0.0818	0.6102
12	0.0703	0.4996
30	0.1074	0.5035
90	0.0793	0.3068

14 days ahead

maturity (τ)	sample1 RMSE	sample2 RMSE
6	0.2245	0.6944
12	0.2058	0.5327
30	0.2037	0.5664
90	0.1788	0.3915

30 days ahead

maturity (τ)	sample1 RMSE	sample2 RMSE
6	0.5195	0.8237
12	0.4039	0.6334
30	0.3991	0.6910
90	0.3371	0.5683

Table 5 – Out-of-sample forecast performance of Diebold-Li procedure with Austrian yield data

From the observations above, one can conclude that within the Diebold-Li two step process with Austrian bond data there is empirical evidence for the main assumption of an influence on yield curve modeling in crisis times. The RMSEs are much higher in the crisis sample which gives evidence for a lower predictive power compared to the first sample. Forecasting interest rates, i.e. the yield level, cannot be done as satisfactorily within the Diebold-Li method with current crisis data, although the absolute values of RMSEs are not very high for the second sample too.

5 Conclusion

The yield curve is one of the leading macroeconomic indicators. The usage is not just limited by the description of various yields of assets due to their maturities, but has also major informational implications. The yield curve can give information about the future economic performance of a country, is a substantial indicator for monetary policy and strategic investment decisions and one can predict the future development of yields (and therefore interest rates). As has been shown by the mentioned empirical studies, the conclusions one can draw from the yield curve according to future inflation are not that clear.

The current financial crisis may disrupt some major assumptions and conclusions drawn from the yield curve. Exploring the effects of the crisis on some elected models of the yield curve was the task of this thesis. After describing the common theories on the yield curve the validity of one theory (expectations theory) was tested by Austrian government bond data. As a result this study found no evidence for a worse fit or applicability of the expectations theory within the data during the crisis.

A standard model from Ang et al. (2004) has been taken to test the main assumption regarding the informational content of the yield curve on future GDP growth rates. Also this empirical analysis came to the conclusion that this model has no worse fit in crisis times. The results have even a little higher statistical significance compared to the results of the non crisis sample.

Only the study on forecasting future yields found some statistical evidence for a worse fit after and during the crisis. To do so the most common model – the Diebold-Li two-step approach – has been applied. Whereas the root mean squared errors of both samples are very small in absolute terms, those of the crisis sample are higher compared to the other. For that reason one can conclude that – with Austrian bond data and the Diebold-Li approach – the information the yield curve can give has less predictive power during the crisis to forecast upcoming yields.

As the current financial and debt crisis is not over now, a further research task could redo this study after the end of the crisis – maybe also with other datasets. An empirical study which focuses on the effects of the information the yield curve can give by comparing it with some other crisis in history, may give a higher understanding of the behavior of the yield curve and its informational content. A generalized statement which says that the yield curve models are not applicable during crisis times cannot be made after this approach.

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7 Appendix

GDP growth and long term yield spread

GDP growth and long term spread during crisis
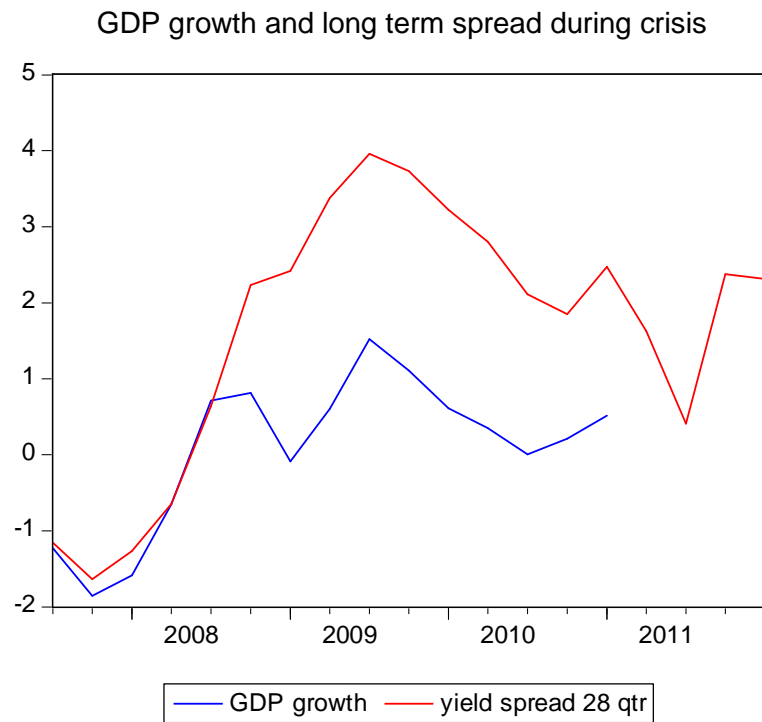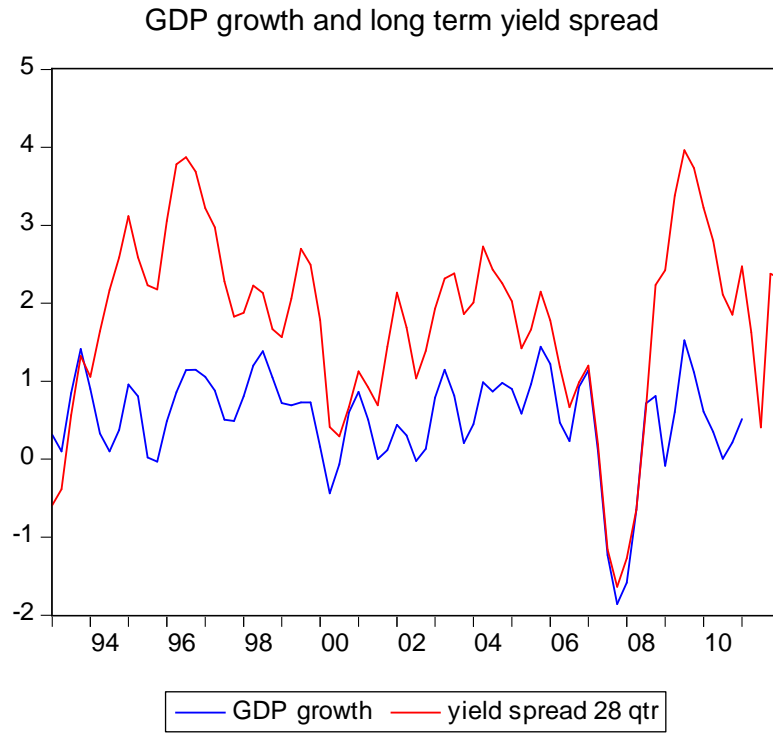
Test of Unit Root

	Augmented Dickey-Fuller Test Statistic		Phillips-Perron Test Statistic	
	sample 1	sample 2	sample 1	sample 2
$\hat{\beta}_{1t}$	-1.579	-6.989	-1.264	-5.365
$\hat{\beta}_{2t}$	-5.822	-11.212	-3.625	-10.251
$\hat{\beta}_{3t}$	-7.287	-13.841	-4.556	-13.888

Plot and PACF of $\hat{\beta}_1$
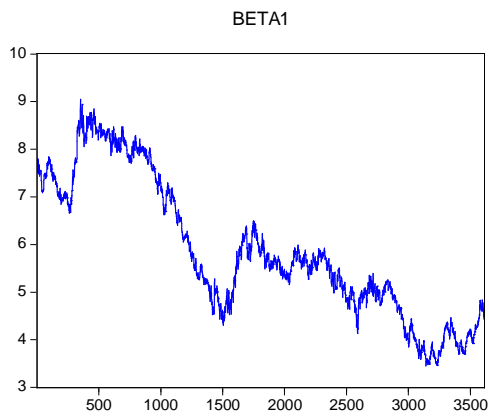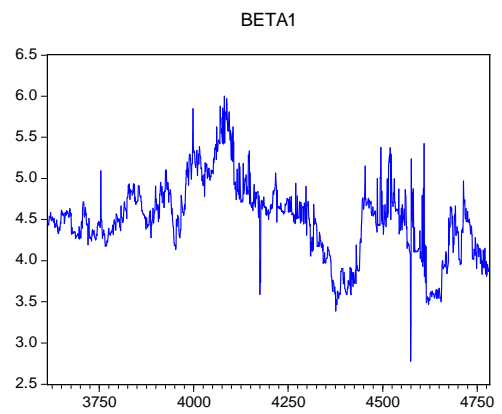
BETA1

BETA1

sample 1

sample 2

Partial Correlation

Partial Correlation

Plot and PACF of $\hat{\beta}_2$

BETA2

BETA2

sample 1

sample 2

Partial Correlation

Partial Correlation

Plot and PACF of $\hat{\beta}_3$

BETA3 (sample 1)

BETA3 (sample 2)

sample 1

sample 2

Partial Correlation

Partial Correlation
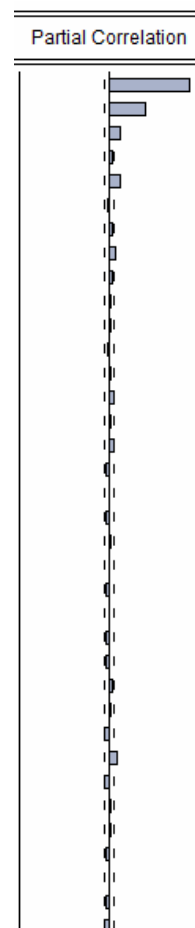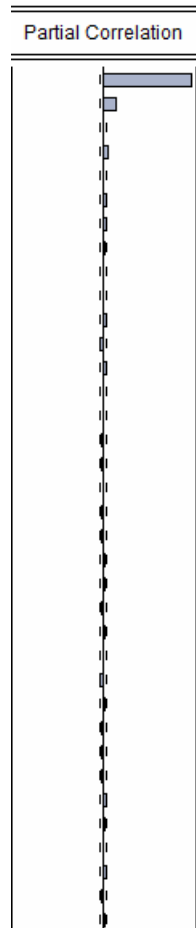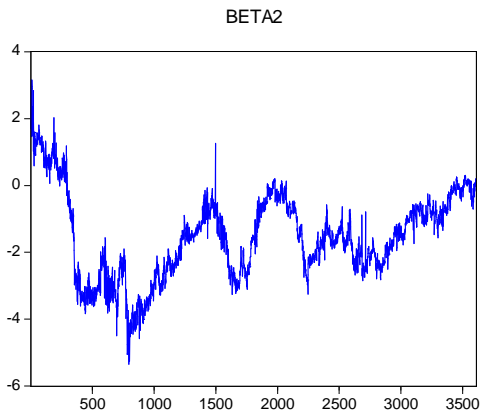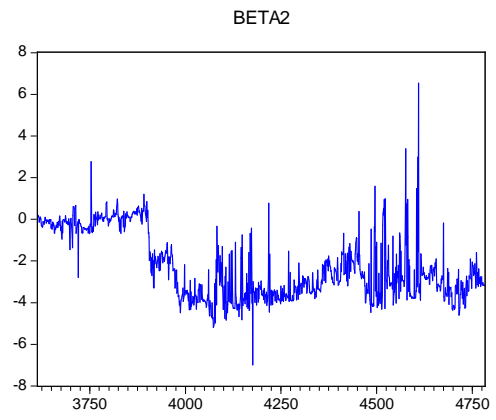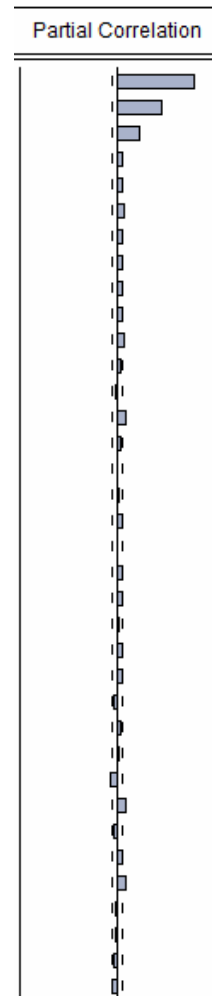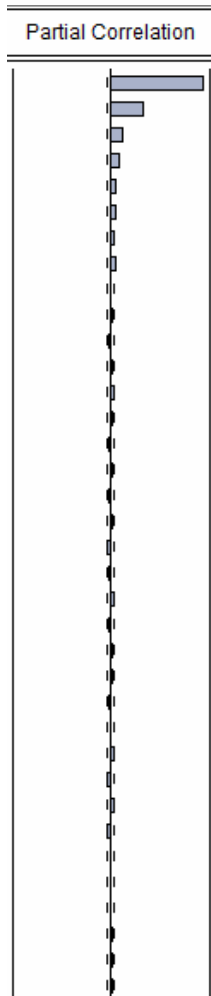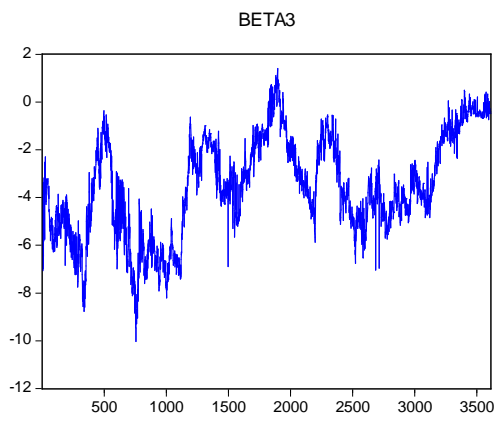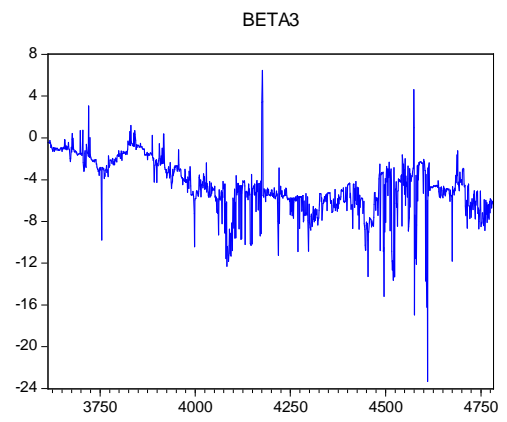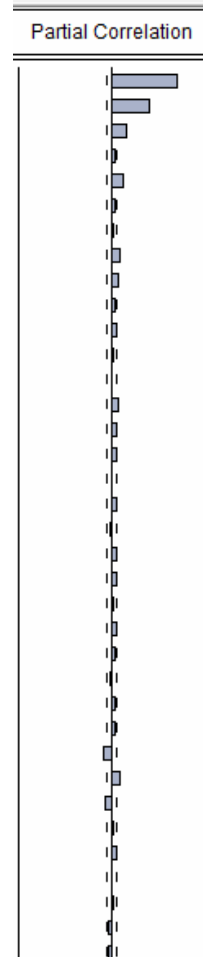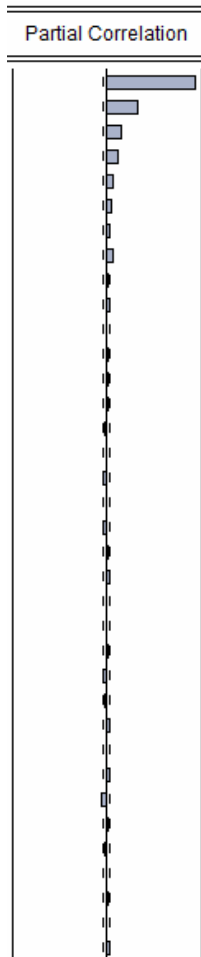
Abstract

The yield curve is one of the leading macroeconomic indicators. One cannot just have a descriptive lock at it, but also extracting important information from it. The informational content of the yield curve is substantial for monetary policymakers and strategic investors. As the financial and debt crisis since 2007 has increased the uncertainty on financial markets and the non-standard measurements of the ECB may have enforced that trend, this thesis wants to explore the effects of the crisis on the informational content of the yield curve. For doing so some elected standard models of the yield curve – like the expectations theory, a model that should predict future GDP growth out of the yield curve and the Diebold-Li model that should forecast the future developments of yields – have been taken. The effect was isolated and tested by splitting the sample of Austrian government bond data into a part before and after/during the crisis and the results of both have been compared. In sum the main assumption – the crisis has a negative effect on the fit of those yield curve models – has not enough statistical significance.

Zusammenfassung

Die yield curve (Zinsstrukturkurve) ist einer der wichtigsten makroökonomischen Indikatoren. Nicht nur kann man diese deskriptiv betrachten, viel interessanter ist der Informationsgehalt der aus dieser Kurve extrahiert werden kann. Diese Informationen sind substantiell für geldpolitische Akteure und strategische Investoren. Da durch die Finanz- und Schuldenkrise seit 2007 die Unsicherheit auf den Finanzmärkten gestiegen ist und die EZB durch die darauf folgenden unkonventionellen Maßnahmen diesen Trend noch verstärkt haben könnte, will diese Arbeit einen möglichen (negativen) Effekt auf den Informationsgehalt der yield curve untersuchen. Um dies zu bewerkstelligen werden einige ausgewählte Modelle zur yield curve – wie die expectations theory, ein Modell welches das BIP Wachstum aus der yield curve prognostizieren soll sowie das Diebold-Li Modell welches zukünftige yields (Zinsen) vorhersagen soll – herangezogen. Um den Effekt zu isolieren und testen wird das sample von österreichischen Staatsanleihen in zwei Teile unterteilt, ein sample bevor der Krise und eines nachher bzw. während der Krise und die Ergebnisse beider mit einander verglichen. In Summe hatte die Annahme – wonach von einem negativen Effekt auf die Anwendbarkeit der yield cuve Modelle durch die Krise ausgegangen wird – nicht genügend statistische Signifikanz.

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