Using the Yield Curve in Predicting Real Economic Growth – Application to Finland

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Economic theory states that the financial markets are forward looking, and that the price of any asset equals the discounted present value of the income generated by holding that asset. The future is, however, uncertain which means that expectations play a large role when investors ponder over what the price of an asset should be. When considering government debt obligations, or bonds, the flow of future income is known with some degree of certainty, since the coupon payments are set in the terms of any bond issue, contrary to e.g. dividends from holding a stock which depend on the company’s success. This means that the uncertainty regarding the real income generated from holding a bond stems from, among other things, the possibility of a sovereign default and inflation. Hence the price of a government bond, and thus the market interest rate (the yield), which are inversely related, reflects the investors’ expectations about the future prospects of a country. It is because of these reasons, that many financial economists have studied the dynamics of the yield curve, which plots the market rates of bonds against their remaining maturities to redemption, and the relationship between the shape of the yield curve and future economic growth. The shape of the yield curve in most of the studies is measured by the difference, or the spread, between long term- and short term market yield of government debt. This relationship between the contemporaneous yield curve shape and subsequent economic growth has been confirmed by a number of studies internationally. However, the results have varied between countries and also in time, which means that the predictive power of the yield curve is probably not structural, but rather depends of country specific characteristics and the type of monetary policy practised by the central bank. While the international literature on the subject is vast, there have not been many studies investigating this relationship with Finnish data. This serves as the main motivation behind this thesis.

The macroeconomic explanation for why such a relationship should exist is based on a model suggested by Arturo Estrella in 2005. The model is constructed from an IS-curve, a Phillips curve and the reaction function of the central bank, as well as the minimisation problem of the central bank’s loss function. This means that the model takes the prevalent monetary policy in to account when considering the ability of the yield curve to predict future growth.

This study employs Finnish quarterly level of GDP data which spans from 1975 to 2011. The contemporaneous yield spread between a 10-year government bond and a 3-month market interest rate (a proxy for the 3-month T-bill rate) is used as a predictor in an OLS-regression to investigate the predictive power with many forecasting horizons and four different model specifications. The time series of the growth rate of GDP shows persistence, and for this reason also the contemporaneous growth rate of the GDP is also included as a predictor. The regressions are first run on the whole sample period, and also on a sub-period 1987 – 2011. This is because before the middle 1980’s the financial markets in Finland were heavily regulated, and hence the interest rates could not effectively reflect the market participants’ expectations about the future.

This study finds that the yield spread is able to predict GDP growth rate in Finland for up to three years in to the future in the latter sample period. The results from the whole sample period were quite poor. Moreover, the contemporaneous yield spread is a better predictor of future growth than the contemporaneous growth rate itself. When considering a rather simple indicator of future growth, these results are encouraging. This is quite impressive especially since many of the international studies find that the predicting power of the yield curve has diminished since the 1980’s, which is contrary to the findings of this study.
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1 Introduction

Interest rates, in general, have a tendency to vary within a business cycle. At times of strong growth increased demand of money and inflation push up interest rates. Conversely, slow growth is usually associated with low borrowing costs. Interest rates of different maturities do not, however, move at the same pace. Short term rates usually move faster than long term rates. One explanation for this is that the central bank is able to affect short term rates indirectly by changing its own refinancing rates or performing open market operations. This is because the interest which the central bank pays to commercial banks on their deposits and the interest rate at which it gives funding to them, make the floor and the ceiling of the interest rates in interbank markets.

As an example, the European Central Bank (ECB) announces three main interest rates. The so called main rate is the interest rate which the ECB uses in its main refinancing operations. These operations are weekly held auctions where commercial banks can make bids for liquidity (loans), typically with a maturity of one week, the main rate being the lowest possible interest rate. This is the rate widely quoted in the press. In addition to these operations, the commercial banks can make deposits to-, and borrow from the ECB overnight at rates called the deposit facility and the marginal lending facility. These facilities set the floor and the ceiling of the interbank EONIA (Euro Overnight Index Average) rate with which the commercial banks fund each other over night. (European Central Bank.)

On the contrary, the central bank can affect, for example, the market interest rate of a 10-year fixed coupon government bond only by buying or selling those very bonds, thus affecting the market price. These types of operations are considered as being unconventional for central banks¹. The different factors behind short- and long term interest rates are explained more thoroughly in chapter 2.

¹ The Federal Reserve has conducted such operations during the financial crisis that began on 2008. Also the European Central Bank has bought Italian and Spanish bonds during the summer of 2011. These operations were not considered as being “normal” monetary policy, since they were carried out to ease the borrowing costs for the countries involved. In addition, the FED was seen as trying to lower borrowing costs for home buyers to boost the housing market. These motives are violating the prevalent view of central bank independency in western economies.
The different pace at which short- and long term interest rates move means that the difference, or spread, between the interest rates of any two interest bearing assets with different maturities will fluctuate over time, and hence, over business cycles. International evidence of the predicting power of the yield curve is encouraging and results have been strong particularly in the United States. This serves as the main motivation behind studying whether similar predicting power applies also for Finland, as carried out in this thesis. In this thesis the information content of the yield curve will consist only of the difference between two rates, the long rate and the short rate. More spreads along the maturity spectrum could be used in order to capture more of the information content, but the purpose of this thesis is to study a relatively simple measure of the yield curve, and its ability to predict real GDP growth in Finland. This study is carried out in chapter 5.

The widely held notion among economists is that financial markets are forward looking, so that ideally the price of a given asset, such as a bond or a stock, should equal the discounted present value (DPV) of future income generated from holding that particular asset. However, since the future is uncertain, the price of an asset today reflects the DPV of expected future income, which is why asset prices should contain some information about the future. It is common to assume rational expectations.

When making decisions about whether to invest in a particular country’s debt or not, it is reasonable to think that investors typically ponder over the future prospects of that country; how will real GDP, consumption or industry output evolve? In addition to macroeconomic variables describing real activity, the rate of future inflation is also important to the investors. This then means that the dynamics of the term structure of interest rates should reflect what the investors think about the future. For example if investors believe that there are inflationary pressures in the economy, and that the central bank is determined to fight it by raising the key refinancing rates if necessary, then this would cause the investors to sell some of their short-term papers, thus lowering the price and pushing the market rate up. Indeed, many previous studies have

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2 This is important especially if the interest on the debt issued by the government is fixed, so that higher inflation lowers the value of the coupon payments.
3 This is because new debt with the same maturity issued by the government would have to pay a better rate of interest, thus being more attractive to investors.
shown that a flattening of the yield curve\textsuperscript{4}, which means that the gap between long- and short term market interest rates shrinks, has been associated with a slowdown of the economy with some lag.

Given this link between the nominal market interest rates, real economic activity and inflation, policy makers and investors should be interested in the information content of the yield curve. The fact that data on the term structure is subject to little or no revision, and that it is available on a daily basis, makes it an obvious candidate for investors and policy makers to follow when considering future movements in the economy.

However, as noted by e.g. Estrella and Hardouvelis (1991), and discussed in more detail in Estrella et al. (2003), the information content of the yield curve may not be stable over time. Essentially this means that the predictive usefulness of the yield curve is not structural, but may be affected by the monetary policy practiced by the central bank, as suggested above, or some other factors. Moreover, Estrella et al. (2003) find that binary models used in predicting e.g. recessions tend to be more stable than continuous models used in predicting changes in the future changes of real activity.

The issues discussed above, especially those concerning monetary policy, make the subject particularly interesting; when presenting empirical results, the contemporaneous monetary policy rule of the central bank should be discussed.

In addition to study the ability of the yield curve to predict real growth in Finland, the purpose of this thesis is to shed light on some of the previous studies concerning forecasting (in sample-) changes in real GNP and real GDP using the slope of the yield curve, as measured by the difference between long and short market rates. These interest rates are typically those of government debt with different maturities to redemption. These studies are addressed in chapter 4. Moreover, it is of particular interest to discuss the economic background as to why such a predictive relationship should exist. Few approaches are discussed in chapter 4, but chapter 3 introduces a full-scale macroeconomic model with a close form solution around the slope of the yield curve, which was proposed by Arturo Estrella (2005). Finally, chapter 6 concludes.

\textsuperscript{4}The yield curve is also known as the \textit{term structure of interest rates}, or just the \textit{term structure}. I will use these expressions interchangeably.
2 The Yield Curve

This chapter introduces the concept of the yield curve and discusses some of the basic theories that try to explain the various shapes of the yield curve actually observed in the credit markets. Basics of pricing a fixed income security are also presented. Theoretical and empirical analysis of the yield curve is itself an interesting and a popular topic in the field of finance, and a thorough investigation of these studies would be beyond the scope of this thesis.

2.1 Pricing of a Bond\(^5\)

Government debt obligations can be roughly divided into two categories: those that pay a fixed amount of money, known as the coupon, on pre-specified dates until maturity, or a redemption date, when the last coupon and the face value are paid, and those that are sold at a discount and promise to pay a single amount, the face value, at some pre-specified date in the future. The former are called simply bonds and the latter are referred to as zero-coupon bonds, zeros or pure discount bonds, in the terminology. Bonds are debt obligations with maturities greater than one year, whereas zero-coupon bonds have a maturity of less than one year at issue\(^6\). In practise, however, any coupon bearing bond can be divided into to several zero-coupon bonds, so that each coupon payment represents a zero-coupon bond with a specified maturity date. This means that zero-coupon bonds with a maturity greater than one year are traded nowadays. (Campbell 1995.)

The price of an m-period zero-coupon bond with a face value of M is simply

\[
p_{mt}^Z = \frac{M}{(1+r_{mt})^m} \tag{1}\]

where \(r_{mt}\) is the spot rate that equates the price of the zero-coupon bond to the present value of its face value. This spot rate will generally be different between zero-coupon bonds with different maturities but otherwise of equal quality. If we think of an m-

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\(^5\) The pricing equations presented in this chapter can be obtained from numerous textbooks. See for example Cuthbertson and Nitzsche (2004, pp. 491-494).

\(^6\) In Finland the state treasury, Treasury Finland, issues so called benchmark bonds with maturities greater than one year and treasury bills, which are zero-coupon bonds with maturities less than one year.
period bond as being a sequence of zero-coupon bonds, then the price of that bond should equal the sum of the present values of those zero-coupon bonds

\[ P_{mt}^B = \frac{C}{1+r_{1t}} + \frac{C}{(1+r_{2t})^2} + \cdots + \frac{C+M}{(1+r_{mt})^m} \]  \hspace{1cm} (2)

where \( r_{it}, i = 1, 2, \ldots, m \) are the spot rates for every pre-specified date a coupon, and finally the face value, is paid.

The yield curve that is actually quoted in the financial press involves a single yield, or a discount rate, for bonds with different maturities, whereas in (2) there is a sequence of spot rates that define the price of a bond. Market participants use (2) to set a price for a given bond. That price is then used to define the yield to maturity, which can be calculated from

\[ P_{mt} = \frac{C}{1+y_t} + \frac{C}{(1+y_t)^2} + \cdots + \frac{C+M}{(1+y_t)^m} \]  \hspace{1cm} (3)

where \( P_{mt} \) is the price of the bond at time \( t \), \( C \) is the fixed coupon payment (in Euros for example), \( M \) is the face value of the bond and \( y_t \) is the yield to maturity at time \( t \). It is easy to see from (3) how the price of a bond is inversely related to its yield to maturity: if the price declines (rises), then the yield must rise (decline). Since the price, coupon payments and the face value are known with some degree of certainty\(^7\), (3) can be used to calculate the yield for bonds with different maturities, which in turn can be used to plot the yield curve.

The simplest way to plot a yield curve is to plot the yield to maturity of every outstanding bond of a given country (or area). There are not, however, outstanding bonds for a continuum of maturities. This means that some sort of interpolation scheme must be used to plot a curve. This is also known as curve fitting. Various techniques exist, the simplest being linear interpolation in which a straight line is drawn between

\(^7\) Government debt is considered to be a risk-free investment in the financial literature, since the coupon payments and the face value of a bond are backed by the full faith of the government and its ability to collect taxes. In financial history governments defaulting on their debts have nevertheless been quite common, so in reality some uncertainty about the future cash flows do exist.
the yields of bonds with different maturities. The Bank of Finland (Bof) uses a fitting method developed in Nelson and Siegel (1987). As an example of the yield curve, the Finnish curve from 10.11.2011 and 09.08.2011 is presented here.

![Figure 1: The Finnish yield curve estimated by the Bank of Finland. Source: The Bank of Finland](image)

From figure 1 it can be seen that the yields of the debt issued by the government of Finland have decreased from September 2011 to November 2011 throughout the maturity spectrum. It is worth noting that the yield in figure 1 is nominal, so that the real yield has actually been negative for many on-the-run bonds at the time of writing this thesis. It may reflect the so called safe haven status enjoyed by the most creditworthy nations during the recent turmoil in financial markets.

### 2.2 Theories of the Yield Curve

Whether investors plan to hold on to their bonds until maturity or sell them before the face value is paid, they will always consider the future when making decisions about the correct price, and hence the yield, of a bond. Most theories that explain the shape and
dynamics of the yield curve are built around the investors’ expectations about future yields throughout the maturity spectrum.

Among the first theories that were developed is the pure expectations hypothesis (PEH). No single author can be credited for developing it, but one of the first to introduce it was Frederick Lutz (1940). If we define a holding period return (HPR) for an m-period bond between periods $t$ and $t+1$ as in Cuthbertson and Nitzsche (2004)

$$H_{m,t+1} = \frac{(P_{m-1,t+1} - P_{m,t} + C_t)}{P_{m,t}}$$

(4)

where $P_{m-1,t+1}$ is the price of the m-year bond next period (when it also becomes an m-1-year bond), $P_{m,t}$ and $C_t$ are the price today and the coupon paid, respectively. The pure expectations hypothesis states that the holding period return should be the same between any two bonds regardless of the maturity chosen

$$E_t H_{m,t+1} = r_t, \forall m$$

where $r_t$ the riskless return over one period, for example a one-year treasury bill. According to PEH, if for example the holding period return of a 5-year bond would exceed that of a 1-year bond, investors would sell the 1-year bond and purchase the 5-year bond. This would increase the current price and lower the yield of the 5-year bond. The opposite would happen to the 1-year bond and eventually the two HPR would be equalised.

The assumption made by the pure expectations theory about the way market participants act is very strong. According to the theory you should expect no difference in returns whether you invest your money in a 1-year or a 30-year bond, as long as the holding period is the same. If the holding period would be, say, one year and there would be no default risk, then investors would know for certain the holding period return of a 1-year bond. However, there is uncertainty considering the price of the 30-year bond one year from today. In addition, the price of a long term bond will change more rapidly than that of a short term bond given any change in yields. In general, when there is uncertainty
about the future, the maturity chosen will have an effect on the expected holding period return (Cox et al 1981).

Another theory, called the *liquidity preference hypothesis*, takes this expected variability in the holding period return into account by introducing a term premium that investors demand for holding bonds with longer maturities

\[ E_t H_{m,t+1} = r_t + T_m \]

where \( T_m \) increases with maturity so that \( T_m > T_{m-1} > T_{m-2} > \ldots \). The term premium increases with maturity precisely because the price risk of a bond is an increasing function of its remaining maturity. This means that for example an upward sloping yield curve need not necessarily imply rising short term rates in the future, but can rather be an indicator of the term premium (or risk premium) (Fabozzi 2005, pp. 155). Whereas the pure expectations hypothesis can be considered as being somewhat naive in the sense that it treats bonds with different maturities equally risky, the liquidity preference hypothesis captures the idea of risk aversion even though it treats the term premium as being a constant over time. It is also possible that the term premium does not grow steadily with maturity. For example during times of turmoil in the asset markets, some government long term bonds can be seen as being safe havens for investors. This has been the case during the financial crisis that started, or accelerated, in 2008; the yields of 10-year bonds of Germany and the United States have declined. This sort of behaviour is often referred to as *flight to quality* or *flight to liquidity* (see for example Longstaff 2002). The quality of, say, 3-month treasury bills and 10-year bonds of these two countries are undoubtedly good but the market for the longer bonds is deeper, meaning that there are plenty of bids and offers in the market at all times, and thus, more liquid and preferable to many investors.

It is possible that, for example, large institutional investors have preferences regarding the maturity chosen when investing in government debt. This view is captured in the *market segmentation hypothesis*, first suggested in Culbertson (1957). In this hypothesis it is argued that investors, such as large pension funds, prefer to match the maturity of their assets to those of their liabilities. Also regulation might impose constraints to the
asset side of their balance sheets, so that for example some proportion of assets must be held at bonds with certain maturities. For the market segmentation hypothesis to hold, bonds of neighbouring maturities should not be close substitutes. This is not necessarily a very realistic assumption, as noted for example in Cox et al (1985).

This chapter introduced some of the basic theories behind the term structure of interest rates. As a common feature, they all share the notion that participants in financial markets are forward looking, and this would suggest that the yield curve dynamics of a given country might tell us something about the future of that country. A macroeconomic approach by Arturo Estrella (2005) is presented in the following chapter.
Arturo Estrella (2005) constructed a full-scale macroeconomic model to explain why the term structure of interest rates might be useful in predicting real economic activity as well as inflation. While most of the earlier papers had informal explanations for this relationship, Estrella’s model is built from an IS curve, a Phillips curve and a monetary policy reaction function. Both backward-looking and forward-looking versions are introduced, so that the model is not dependent on a single paradigm of macroeconomic modelling. The inclusion of the central Bank’s reaction function is important because the relationship between the yield curve and subsequent growth might not be policy invariant. This chapter introduces the key points of Estrella’s model.

The backward-looking IS curve has the form

$$ y_t = b_1 y_{t-1} - b_2 \rho_{t-1} + \epsilon_t, $$

where $y_t$ is the output gap as measured by the log difference between actual and potential output, $\rho_t$ is the long term real interest rate and $\epsilon_t$ is a zero-mean shock. The long term interest rate refers to a two-period interest rate and periods are measured in years. The parameters are expected to satisfy $0 < b_1 \leq 1$ and $b_2 > 0$. The backward-looking Phillips curve has the form

$$ \pi_t = \pi_{t-1} + a y_{t-1} + \epsilon_t, $$

where $\pi_t$ is the one-period inflation rate, $\epsilon_t$ is a zero-mean shock and $a > 0$, so that a positive output gap adds inflationary pressure in the economy. The “textbook version” of the (short run) Phillips curve relates inflation and unemployment inversely, so that growing unemployment is associated with slower inflation. Equation (6) also captures that idea since a positive output gap has a negative impact on unemployment.

The backward-looking macroeconomic equations have the nice property, that they fit the time series well in Estrella’s empirics. However, they do not have as solid

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8 This chapter is built entirely on the work by Arturo Estrella (2005), unless stated otherwise.
theoretical footing as their forward-looking counterparts, as the prevalent view among most economists seems to be that economic agents are forward looking, and thus their expectations about the future should play a role in today’s economic conditions.

The forward-looking IS curve is

\[ y_t = E_t y_{t+1} - \beta \rho_t, \] (7)

where \( E_t y_{t+1} \) is the expected output gap in period \( t+1 \) formed today and \( \beta > 0 \). The zero-mean shock terms are omitted from the forward-looking equations for simplicity.

The forward-looking Phillips curve is given by

\[ \pi_t = E_t \pi_{t+1} + \alpha y_t, \] (8)

where \( \alpha > 0 \). Estrella notices that when estimating these types of forward looking equations, the parameters tend to have the wrong sign, i.e. they are negative.

We now turn to the monetary policy reaction functions, in which the central bank sets the short term nominal interest rate in response to deviations of inflation from its desired level, and output from its potential level. The short term interest rate set by the central bank typically does not change rapidly, and for this reason also a lagged short term rate is added to the reaction function. The current-information reaction function, where the monetary authority reacts to realised inflation, is of the form

\[ r_t = g_r r_{t-1} + g_\pi \pi_t + g_y y_t + (1 - g_r - g_\pi) \pi^*, \] (9)

where \( r_t \) is the short term nominal interest rate, \( \pi^* \) is the desired level of inflation (or target rate) and the parameters satisfy \( 0 \leq g_r \leq 1, g_\pi > 0 \) and \( g_y > 0 \). If we rewrite (9) as

\[ r_t = g_r r_{t-1} + g_\pi (\pi_t - \pi^*) + g_y y_t + (1 - g_r) \pi^* \]

it is easy to see that the central bank reacts to deviations of inflation from its target\(^9\), so that when, for example,

\[^9\) The coefficient of the inflation target has its particular form for convenience; \((1 - g_r - g_\pi)\) makes the equation linear homogenous in \( r_t \) and \( \pi_t \).\]
the central bank will react and raise the short term nominal interest rate. Estrella also introduces a forward-looking version of the reaction function but it is not used in the final model, because the forward-looking version is a simple transformation of (9), namely \( g_y' \) in the forward looking model is replaced with \( g_y + g_\pi \alpha \), where \( \alpha \) is obtained from (8) and \( g_\pi' = g_r, g_\pi = g_\pi. \)

What is particularly interesting in (9) is that if the coefficient of the lagged interest rate is allowed to be zero, \( g_\pi = 1.5 \) and \( g_y = 0.5 \), then it corresponds to the well-known Taylor (1993) rule.

The last two equations needed to solve the macroeconomic model link the two-period nominal interest rate to the corresponding real interest rate (the Fisher equation), and to the expected future one-period rate (the expectations hypothesis of interest rates). The Fisher equation has the form

\[
R_t = \rho_t + \frac{1}{2} (E_t \pi_{t+1} + E_t \pi_{t+2}),
\]

where \( R_t \) is the nominal two-period interest rate and \( \rho_t \) is the real two period interest rate. Equation (10) states that the nominal two-period interest rate is the real rate plus the average of contemporaneous expectations concerning inflation one- and two periods ahead. The expectations hypothesis of interest rates is simply

\[
R_t = \frac{1}{2} (r_t + E_t r_{t+1})
\]

and it expresses the nominal two-period interest rate as the average of current short rate and the expected short rate.

The full backward-looking model is then constructed from the equations (5), (6), (9), (10) and (11). In the forward-looking version the equations (5) and (6) are replaced with (7) and (8). The quite complex details of the solutions to both cases are not carried out.

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10 The forward-looking reaction function is \( r_t = g' r_{t-1} + g_\pi' E_t \pi_{t+1} + g_y' y_t + (1 - g_r' - g_\pi') \pi^* \). Substituting \( E_t \pi_{t+1} = \pi_t - \alpha y_T \) we get \( r_t = g_r r_{t-1} + g_\pi \pi_t + (g_y' - g_\pi' \alpha) y_t + (1 - g_r - g_\pi) \pi^* \) and finally substituting \( g_y' = g_y + g_\pi \alpha \) we get \( r_t = g_r r_{t-1} + g_\pi \pi_t + g_y y_t + (1 - g_r - g_\pi) \pi^* \), which is (9).
in this thesis, since the emphasis of this work is on the empirics of the Finnish data. We next turn to the relationships between the yield curve, or its slope, and future output and inflation.

The following solutions make use of the solutions to the systems of equations presented above. These two equations relate future output and inflation to the slope of the yield curve, and to deviation of inflation from its target and the output gap. After presenting these equations, the optimal parameter values from the minimisation problem of the central bank are used to give the final predictive equation for future output. The backward-looking solutions are

\[
E_t y_{t+1} = \frac{2}{g_y} (R_t - r_t) + \frac{1-g_r}{g_y} (r_t - \pi^*) + \frac{g_\pi}{g_y} (\pi^* - \pi_t - ay_t) \quad (12)
\]

and

\[
\frac{1}{2} E_t \Delta \pi_{t+2} = \frac{a}{g_y} (R_t - r_t) + \frac{a(1-g_r)}{2g_y} (r_t - \pi^*) + \frac{ag_\pi}{2g_y} (\pi^* - \pi_t - ay_t) \quad (13)
\]

Note that (12) and (13) differ only by a scalar so that \( \left( \frac{a}{2} \right) E_t y_{t+1} = \frac{1}{2} E_t \Delta \pi_{t+2} \). The remainder of this chapter will focus on predicting output, since inflation is not the focus of this thesis. Disregarding, at this point, the monetary authority’s optimisation problem, it is easy to see from (12) that if e.g. \( g_r = 1 \) and \( g_\pi = 0 \), so that the central bank focuses only on the output gap, the second and the last term disappear, leaving the yield spread as the single predictor of future output.

It was argued earlier that the form of monetary policy practised might affect the predictive power of the yield curve. To examine this in more detail Estrella introduces a central bank’s optimisation problem, and substitutes the optimum parameter values to the general model that consists of the equations (12) and (13). The objective function presented in the paper is

\[
\min_{(g_r, g_\pi, g_y)} E_t \sum_{i=1}^{\infty} \delta^i \left[ \frac{1}{2} \left( (1 - w) (\pi_{t+i} - \pi^*)^2 + wy_{t+i}^2 \right) \right], \quad (14)
\]

where \( 0 < \delta < 1 \) is a discount factor reflecting that the central bank is more concerned about the present than the future, and \( 0 \leq w \leq 1 \) is the relative weight with which the
central bank reacts to fluctuations in the output gap. If $w = 0$, then the central bank can be said to practise so called strict inflation targeting, and when the weight lies between zero and one, the central bank has interest also in the stability of output. The latter approach seems intuitively more plausible, even if e.g. the European Central Bank has been somewhat “hawkish” in the past.

Finally, when the optimal values from (14) are substituted to (12), the backward-looking predictive equation for output, including the central bank’s optimal behaviour with the given objective function, is obtained

$$E_t y_{t+1} = \frac{2b_2(R_t-r_t)+b_1y_t}{ab_2+2(1+2b_1)(1-\mu)+2b_1\mu} \tag{15}$$

where $\mu = \frac{2\theta}{1+\theta}$ and $0 \leq \theta(w) \leq 1$ is a function of $w^{11}$, with $\theta(0) = 0$ and $\theta(1) = 1$. The optimal parameter values for (14) are expressed in terms of the monetary policy reaction function (9), so that monetary policy affects also (15), and thus the ability of the yield spread to predict future growth. Also, as $\mu$ varies between 0 and 1 in response to changes in the relative weight on output gap targeting, $w$, it affects only the relative weights of the terms in the denominator.

The full-scale macroeconomic model introduced by Estrella builds a link between the IS curve, the Phillips curve, the Fisher equation, the expectations theory of interest rates, monetary policy reaction function and the optimal behaviour of the central bank while replacing the traditional use of short term interest rates with the spread between a 2-year rate and a 1-year rate. Estrella’s empirical estimation of the equations in the model finds supporting results for the parameters suggested by the theory. Further empirical investigation of the model, especially on an international basis, should be an interesting subject of study in the future. However, what makes the model difficult to estimate is the fact that annual data needs to be employed, since in the model the periods refer to years. This means that gathering a sufficiently large time series for reliable estimation might prove as an obstacle.

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11 The details, and motivation, for the use of $\mu$ and $\theta(w)$ can be found from the technical appendix of Estrella’s (2005) paper.
Estrella’s model serves as a theoretical justification for studying the empirical link between the slope of the yield curve and subsequent economic growth in Finland. Before we turn to the Finnish case, some previous studies regarding this relationship are introduced in the next chapter.
4 International Empirical Studies

The information content of the yield curve with regard to real economic output has been a popular subject of study since at least the late 1980’s. Various studies have found that the yield spread can help predict subsequent real economic activity. Some of these studies use simple OLS regression models in predicting future real activity, while others employ probit models to predict the probability of a future recession. This section introduces some of the former.

The previous results vary from country to country and also depend on the time period chosen within a country. This suggests that the predictive power is probably neither structural nor time invariant, but rather depends on country-specific characteristics such as the targeting of monetary policy or the sensitivity to different types of shocks hitting the economy, which are not necessarily stable over time (Estrella et al. 2003). More specifically, the predictive power of the yield spread is reactive to the parameters in the monetary authority’s reaction function regarding deviations of inflation from its target, and actual output from potential (Estrella 2005).

In contrast to most of the literature regarding the subject, Harvey’s (1988) paper introduces a Consumption Capital Asset Pricing (CCAPM) type of model to predict future consumption growth using the real term structure. The basic idea behind the CCAPM is that the representative agents maximise their expected utility from consumption over time, so that they can choose to consume today or invest in financial assets in order to have more purchasing power in the future. This way the agents’ current consumption possibilities do not rely solely on current income. Harvey’s motivation for the use of CCAPM is that since real interest rates affect the agents’ saving decisions, and current income is either consumed today or saved (invested), the real rates should also have an effect on consumption patterns. Consumption on the other hand affects GDP growth, which links Harvey’s study to this thesis. Harvey finds that there is information about future consumption growth in the term structure, especially with two and three quarters’ forecast horizons. Lagged yield spread provided better forecasts than lagged consumption or stock returns, in the sense that the root mean squared errors (RMSE) were smaller. The regression model is

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12 For more details about the CCAPM see for example Cuthbertson and Nitzsche (2004, pp. 303–322).
\[ \Delta c_{t+1:t+j} = \beta_0^j + \beta_1 y_{t,t} + \beta_2 r_{1,t} + u_{j,t+j}, \quad j = 1, 2, 3. \] (16)

where \( \Delta c_{t+1:t+j} \) is the per capita growth in real consumption of nondurables and services between periods \( t+1 \) and \( t+j \), \( y_{t,t} \) is the spread between expected real yields of \( j \)-quarter maturity and 1-quarter maturity government debt, and \( r_{1,t} \) is the expected real yield of 1-quarter maturity government debt. The expectations are simulated by making out-of-sample forecasts of the inflation rate at every period, which is then subtracted from the nominal rates to get the expected real rates. For more details see Harvey 1988, pp. 309. The data from the United States ranges from 1953:1 to 1987:1, and the coefficients of the model are estimated using the entire sample period, as well as subsamples (1953:1 – 1971:4) and (1972:1 – 1987:1). The results are quite poor in the first subsample; the coefficients of the yield spread are not statistically significant in any of the \( j \)-period-ahead forecasts, and they are also negative whereas the coefficients using the whole sample period and the latter sample period are positive. The results are strongest in the latter sample period with statistically (at least at the 10% level) significant coefficients in all forecast horizons. The highest coefficient of determination, \( R^2 \), is 0.31, which is extracted from the model predicting growth three quarters ahead, and the sample period (1972:1 – 1987:1).

When comparing alternative regression models using lagged values from stock returns and consumption as predictors, Harvey simply runs the two extra regressions and compares the RMSEs of the three models. Had he included, say, lagged consumption in the same regression with the yield spread, we would have been able to see whether there is information in the yield spread over and above lagged consumption. However, the models using lagged consumption and stock returns explain only a small fraction of the variation in subsequent consumption growth. The \( R^2 \) in these models ranges from 0.01 to 0.06, suggesting that the yield spread is a better predictor of consumption growth. Despite the weaknesses in the early work by Campbell Harvey, it can be considered important since the reasoning as to why there should be predictive power in the yield curve was based on an explicit model, while in most of the contemporaneous papers the explanations were more heuristic (Estrella 2005).
Most of the studies investigating the links between the yield curve and real economic activity have focused on broader aggregates than expenditure on consumption, and typically use a wider maturity spectrum of the yield curve as a predictor. While Harvey used the spread between a 1-year US Treasury bond and a 3-month US Treasury bill when making forecasts 3 quarters ahead, in many papers the ‘long yield’ is taken from further down the maturity spectrum; 2,5, 10 and even 20-year bond yields are used\(^\text{13}\).

One of the most comprehensive econometric studies on the subject is the paper written by Arturo Estrella and Gikas Hardouvelis (1991). They run both continuous and discrete regressions and find that the yield curve contains in-sample information about future real activity and the probability of a future NBER (National Bureau of Economic Research) dated recession, respectively. Their basic regression is of the form

\[
Y_{t,t+k} = \alpha_0 + \alpha_1 SPREAD_t + \sum_{i=1}^{N} \beta_i X_{it} + \varepsilon_t, \tag{17}
\]

where \(Y_{t,t+k}\) is the annualised cumulative percentage change in real GNP and \(k\) is the forecasting horizon in quarters, \(SPREAD_t\) is the difference between the 10-year US Treasury bond yield and the 3-month US Treasury bill yield, and \(X_{it}\) are the other information variables included in the regression.

Estrella and Hardouvelis recognise that since the sampling period is quarterly, but the forecasting horizon \(k\) varies from 1 to 20 quarters, the data overlaps. This creates a moving average error term of order \(k - 1\), and they use Newey and West (1987) adjusted standard errors for correct inference. The time series ranges from 1955:2 to 1988:4.

When using only the yield spread as an explanatory variable, Estrella and Hardouvelis find that it contains information about cumulative GNP growth rate for up to 4 years into the future. Cumulative growth rate in this context means, for example, the annualised growth rate 4 years ahead from today. This model can explain about one third of the variation in the cumulative growth rate. The predictive power regarding future marginal GNP growth rate lasts for up to 6 quarters ahead, but the \(R^2\) is less than

\(^{13}\) Laurent (1988) uses the spread between a 20-year bond and the federal funds rate to predict growth in real GNP in the United States.
0.1 after 3 quarters’ forecasting horizon. By marginal growth rate they mean the annualised growth rate from some future quarter \( t+k-j \) to some future quarter \( t+k \). The coefficient of the yield spread is positive in both cases, reflecting that lower short rates induce investments and have a positive effect on subsequent growth. They also find out that the yield curve has predictive power over and above several variables that are thought to help predict future growth. These variables include the real federal funds rate, the index of leading indicators\(^{14}\), lagged GNP growth, and lagged inflation. With these four variables included, the yield spread continues to have significant predictive power for up to 12 quarters ahead.

Estrella and Hardouvelis do not base their explanation as to why this kind of predictive relationship exists to any explicit model, but they recognise, in the spirit of the well-known Lucas (1976)\(^{15}\) critique, that even if the yield curve has contained useful information for private investors as well as to policy makers in the past, this is not necessarily the case in the future. In other words, the information content might not be policy invariant. They assess the argument that the information content would only reflect current monetary policy by running a regression with the real federal funds rate as the sole additional predictor, and find that the yield spread continues to have significant predictive power in both cumulative and marginal GNP growth. Thus, from the mid 1950s to late 1980s, the yield spread contained mostly information other than current monetary policy. They note, however, that this would change if the Federal Reserve would contain the yield curve as an information variable in its decision making.

Contemporary papers by Nai-Fu Chen (1991) and James Stock and Mark Watson (1989), among others, find supporting results for the predictive power of the yield spread. Chen finds similar results to those of Estrella and Hardouvelis (1991); the yield spread can predict changes in the marginal real GNP growth rate for up to 5 quarters ahead. Stock and Watson construct an index of leading economic indicators, and include two different yield spreads to this index.

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\(^{14}\) The index of leading indicators consists of twelve macroeconomic variables presumed to have predictive power over real GNP growth.

\(^{15}\) Lucas argued that any changes in economic policy would alter the structure of econometric models that try to predict the consequences of those very changes. In other words, the parameters in the models were not policy invariant.
Later work has focused on examining whether similar relationships can be found on an international level, but more importantly, economic explanations considering the relationship between the term spread and real activity have been developed.

Among the studies that base the explanatory power to a well-known economic theory is the paper written by Charles Plosser and Geert Rouwenhorst (1994). They base their explanation on the Real Business Cycle theory (RBC), which suggests that there should be a relationship between real interest rates and expected future real growth. Thus real yield spreads should reflect expected differences between near and distant future real output growth. However, while the RBC applies to real interest rates, they use nominal interest rates in the study. This weakens the link between theory and empirics, as pointed out by Estrella (2005).

Plosser and Rouwenhorst also present international evidence regarding the information content of the yield curve. The data is collected from the United States, the United Kingdom and Germany, and it ranges from August 1973 to December 1988. Monthly industrial production is used as a proxy for GNP in order to be able to use the data on interest rates more effectively. They find that nominal yield spreads are able to predict future industrial production in all three countries. Interestingly, in the case of United Kingdom, the various yield spreads predict nominal growth better than real growth, whereas the opposite holds for the other two countries. Their explanation is that inflation was much higher in the UK during the sample period, which obscures the information in the yield curve considering real activity, thus primarily reflecting inflation expectations. Also this calls for the use of real interest rates.

These early studies were important in that they confirmed the empirical relationship between the slope of the yield curve and subsequent economic growth. However, with Harvey (1988) being the exception, these studies did not allude to any explicit theoretical framework behind the explanatory power. This means that, while important, these studies were to a large extent empirical, even though economic explanations were

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16 The use of real yield spreads would have required for example subtraction of expected inflation from the nominal interest rates, as in Harvey (1988).

17 Plosser and Rouwenhorst use the differences $i^k_t - i^1_t$, where $k$ is the forecasting horizon in years.
discussed. We next investigate the link between the yield spread and subsequent growth in Finland.
5 Empirical Evidence from Finland

While the literature investigating the relationship between the yield curve and future economic output has been vast internationally, the same does not hold for Finland, possibly due to lack of quality data given that the financial markets in Finland were heavily regulated until the late 1980’s. This regulation meant that, for example, the market interest rates could not effectively reflect market participants’ expectations about the future. Commercial banks were mainly financed through the Bank of Finland and capital was not allowed to flow freely across the national borders.

Financial regulation was gradually removed during the 1980’s and key steps were made in 1986 when foreign lending was allowed for private firms and the interest rates charged by commercial banks from their loans were no longer regulated (Kiander 2001). Heavy regulation up to the late 1980’s means that there is probably at least one structural brake in the data used, which spans from 1975:1 to 2011:1.

This chapter presents empirical evidence of the relationship between the contemporaneous yield spread and subsequent real economic growth in Finland.

3.1 Methodology

The study is carried out using standard Ordinary Least Squares (OLS) regression between the growth rate of GDP and the difference between 10-year and 3-month interest rates in the fashion of the widely cited study by Estrella and Hardouvelis (1991). I use OLS-regression as the method of choice since most international studies have used it, and thus making comparisons between Finnish and international results is quite straightforward. Two separate effects are investigated; the annualised cumulative percentage change in GDP and the annualised marginal percentage change in GDP. The cumulative change in GDP tries to answer the question of how much can we expect the economy grow on a yearly basis over the next, say, two years given the contemporaneous yield spread. The marginal change in GDP seeks to answer the question of how much can we expect the economy to grow on a yearly basis, say, one year from now to one and a half years from now given the current yield spread.
The data on both the GDP and the two interest rates is quarterly and thus the annualising factor is 400 divided by the corresponding forecasting horizon. The annualised cumulative change in GDP from quarter $t$ to quarter $t+k$ is defined by

$$GDP_{t,t+k} = \frac{400}{k} (\ln GDP_{t+k} - \ln GDP_t)$$  \hspace{1cm} (18)

where $k$ is the forecasting horizon in quarters and $GDP_{t+k}$ is the level of real GDP in quarter $t+k$. The annualised marginal change in GDP from future quarter $t+k-j$ to future quarter $t+k$ is defined by

$$GDP_{t+k-j,t+k} = \frac{400}{j} (\ln GDP_{t+k} - \ln GDP_{t+k-j})$$  \hspace{1cm} (19)

where $j$ is the forecasting horizon in quarters. The contemporaneous “slope” of the yield curve is used as a predictor, and it is defined as the difference, or spread, between the yield of a 10-year government bond and a 3-month market interest rate (more details on the data below)

$$SPREAD_t = R_t^{(10y)} - R_t^{(3m)}$$  \hspace{1cm} (20)

where the superscripts $10y$ and $3m$ refer to the two interest rates. Finally, the regression models for cumulative and marginal growth are

$$GDP_{t,t+k} = \alpha_0 + \alpha_1 SPREAD_t + \epsilon_t$$  \hspace{1cm} (21)

and

$$GDP_{t+k-j,t+k} = \beta_0 + \beta_1 SPREAD_t + u_t$$  \hspace{1cm} (22)

where $\epsilon_t$ and $u_t$ are moving average (MA) error terms of order $k-1$ and $j-1$, respectively. The MA-errors terms are generated because the sampling frequency is quarterly but the forecasting horizons $k$ and $j$ vary from 1 to 12 and from 1 to 4 quarters, respectively, in this study. Due to this data overlapping problem heteroscedasticity and autocorrelation (HAC) robust standard errors of the type Newey and West (1987) will be used for correct inference. The Newey-West estimators use $k-l$ lags with the model
specifications that predict future cumulative changes in real GDP and \( j-1 \) lags in the model specifications that predict future marginal changes in real GDP, according to the respective forecasting horizons.

5.1 Data

The Finnish GDP data is seasonally adjusted quarterly level of real GDP in reference year 2000 Euros, obtained from Eurostat. The sample period is from the first quarter of 1975 to the first quarter of 2011. The regressions (21) and (22) will be run first on the whole sample period and then on the period 1987:1-2011:1 due to the change in the regulatory regime in Finland. Figure 2 shows the level and growth rate of Finnish GDP from 1975:1 to 2011:1. The depression of the early 1990’s and the more recent heavy contraction in 2009 are shown clearly from the figure and they probably have a bad impact on the regression results, or the fit, as well. The differenced series is stationary according to the Augmented Dickey-Fuller test (ADF). When the forecasting horizon is increased, the series starts to transform into a smoother process. The ADF-test finds some evidence, depending on the lag length chosen, of a possible unit root in the processes. However, it could be argued that a unit root in a series that tracks the growth rate of a nation sounds somewhat peculiar, since the growth rate cannot wander off indefinitely to either direction. Nevertheless, the growth series do show significant persistence and for this reason lagged values of the GDP growth will be added as additional explanatory variables after investigating the relationship with a single regressor, the contemporaneous yield spread.
Figure 2: Natural logarithm of Finnish GDP in reference year 2000 price level (upper panel) and the annualised quarter-to-quarter growth rate of GDP in Finland (lower panel)

The 10-year interest rate data is the market yield of the 10-year Finnish Treasury bond measured quarterly from 1975:1 to 2011:1. The data is point-in-time and it is taken from the middle of the quarter, that is, 15.2, 15.5 and so on. The 3-month interest rate is the...
market interest rate in Finland\textsuperscript{18}. In this context it is used as a proxy for the yield of the 3-month Treasury bill, because the market for those is not as big and liquid as would be preferable for reliable analysis. The data is obtained from the Bank of Finland.

![Figure 3: 3-month market interest rate (red) and 10-year Treasury bond yield (black), quarterly data.](image)

Figure 3 shows the two interest rates from 1975:1 to 2011:1. It is easy to see that during the heavy regulation and high inflation period of the late 1970’s and early 1980’s both rates were very high. Moreover short rates were usually higher than long rates, which has been quite rare after the regulation was relaxed during the late 1980’s. The two series show a clear downward trend and the ADF-test shows that both series have a unit root. However, looking at figure 4 we can see that the difference between the two series, that is, the spread, does not have at least a clear trend. The argument considering the possible unit root in this time series is the same as with the GDP growth rate series; the differenced series is highly unlikely to wander of indefinitely to either direction, but there is clearly persistence in the series.

Looking at figure 4, it is also evident that the early data differs from that of the more recent past.

![Figure 4: The difference (spread) between 10-year Treasury bond yield and the 3-month market interest rate.](image)

5.2 Results

The regressions (21) and (22) are first run on the entire sample period from 1975:1 to 2011:1. The regressions seeking to predict the cumulative percentage change in GDP use six different forecasting horizons, $k$: 1, 2, 4, 6, 8 and 12 quarters ahead. In the regressions for the marginal percentage change in GDP the forecasting horizon, $j$, is 1 for $k=1,2$, 2 for $k=2,4,6,8$ and 4 for $k=12$. The results from the entire sample period for the cumulative change of GDP are shown in table 1.
Table 1: Regression results for the cumulative change in GDP. Sample period 1975:1 – 2011:1. Newey and West (1987) adjusted standard errors are inside the brackets. Significance codes: 0.10’, 0.05*, 0.01** and 0.001***. $\bar{R}^2$ is the adjusted coefficient of determination and SER is the standard error of the regression.

Table 1 shows that the yield spread is a significant predictor for cumulative change in GDP for only up to two quarters ahead at the 10% significance level, which after it is no longer significant. The coefficient of the yield spread is positive, which means that an upward sloping yield curve should be associated with positive subsequent growth. The intercept is positive and significant for up to one year in to the future. This tells us that a negative slope is not necessarily associated with negative subsequent growth. However, the model can explain only up to 7% of the variation in the growth rate of real GDP. This is a rather poor result and it might be due to economic conditions at the early end of the GDP series discussed above. The results for the marginal change with the same sample period are shown in table 2.
Forecasting horizon, \( k, j \)

\[
\frac{400}{j} (\ln GDP_{t+k} - \ln GDP_{t+k-j}) = \beta_0 + \beta_1 \text{SPREAD}_t + u_t
\]

<table>
<thead>
<tr>
<th>Forecasting horizon, ( k, j )</th>
<th>Observations</th>
<th>( \beta_0 )</th>
<th>( \beta_1 )</th>
<th>( R^2 )</th>
<th>SER</th>
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<tbody>
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<td>(0.23)</td>
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Table 2: Regression results for the marginal change in GDP. Sample period 1975:1 – 2011:1. Newey and West (1987) adjusted standard errors are inside the brackets. Significance codes: 0.10’, 0.05*, 0.01** and 0.001***. \( R^2 \) is the adjusted coefficient of determination and SER is the standard error of the regression.

Table 2 shows that the yield spread predicts future marginal growth very poorly. Observe that the model specification for marginal changes in real GDP is the same as that of the cumulative changes when \( k=j=1 \). The predictive power of the yield spread fades out after six months and the model is able to predict even less variation of the marginal change in GDP than the model specification (21). After six quarters there is no explanatory power whatsoever left in the model.

For the reasons discussed above, we now investigate whether the regressions (21) and (22) fare better in predicting real GDP growth in the sample period from the first quarter of 1987 to the first quarter of 2011. The time series’ will be substantially shorter but the minimum amount of observations, with the maximum forecasting horizon, will still be
85, which should be sufficient for reliable analysis. The results for the cumulative change in real GDP are presented in table 3.

\[ GDP_{t,t+k} = \frac{400}{k} (\ln GDP_{t+k} - \ln GDP_{t}) = \alpha_0 + \alpha_1 \text{SPREAD}_t + \epsilon_t \]

<table>
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<th>Forecasting horizon, k</th>
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Table 3: Regression results for the cumulative change in GDP. Sample period 1987:1 – 2011:1. Newey and West (1987) adjusted standard errors are inside the brackets. Significance codes: 0.10’, 0.05*, 0.01** and 0.001***. \( \bar{R}^2 \) is the adjusted coefficient of determination and SER is the standard error of the regression.

Table 3 shows that the results from the shorter sample period are significantly different. The yield spread is now able to predict changes in the annualised cumulative change of real GDP up to three years in to the future, and the intercept is no longer a significant predictor with any forecasting horizon. The model is also able to explain almost half of the variation in the dependent variable from one to three years in to the future.

While this is impressive, it must be emphasized that the time series for the cumulative change in GDP starts to show significant persistence when the forecasting horizon is increased. This means that it is essential to include a lagged value, or many lagged values, of the dependent variable to see whether there is explanatory power in the yield spread over and above the lagged values of the dependent variable. Strangely, the issues
of persistence in the time series were ignored, for example, in the influential study by Estrella and Hardouvelis (1991). A thorough discussion of the econometric shortcomings in the early studies of the subject can be found from e.g. Stock and Watson (2003).

Finally, the results for the annualised marginal change in real GDP are presented in table 4.

\[
GDP_{t+k-j,t+k} = \frac{400}{j} (\ln GDP_{t+k} - \ln GDP_{t+k-j}) = \beta_0 + \beta_1 \text{SPREAD}_t + u_t
\]

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<td>(2.86)</td>
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Table 4: Regression results for the marginal change in GDP. Sample period 1987:1 – 2011:1. Newey and West (1987) adjusted standard errors are inside the brackets. Significance codes: 0.10’, 0.05*, 0.01** and 0.001***. \(R^2\) is the adjusted coefficient of determination and SER is the standard error of the regression.

As with the full sample period 1975:1 – 2011:1, the marginal predictive power is not as strong as the cumulative predicting power. The results are nevertheless impressive; the yield spread remains a significant predictor at the 5% level up to two years in to the future. For example, if the yield spread today was 100 basis points (1%), then the
regression would predict the economy to grow 1.43%, on a yearly basis, between one year from now and one and a half years from now (k=6, j=2).

We now continue investigating the in-sample predictive power of the yield spread in the latter sample period from 1987:1 to 2011:1. It was argued earlier that the growth rate of GDP series shows persistence, which suggests that the contemporaneous growth rate might also help predict future growth. And more importantly, before judging whether the yield spread is able to predict future growth or not, it is essential to see whether it predicts growth over and above the lagged value of growth itself.

The augmentation of the model could be done in several ways. For example, we could add several autoregressive components of past quarter-to-quarter growth rates. The purpose here, however, is to see how we can look at some relatively simple indicators today and try to answer the question “How can we expect real GDP to evolve in the future, given the contemporaneous yield spread and current growth rate of the GDP?”.

Both of these indicators are readily available; the financial press publishes market yields on a daily basis, and the growth rate of the GDP is published quarterly by several institutions, such as Statistics Finland\textsuperscript{19}.

As an indicator of current economic performance in Finland, we choose the percentage growth of GDP within a year, that is, from quarter \( t-4 \) to quarter \( t \). We could choose differently, for example, the annualised growth rate during the recent quarter. Quarterly growth rates tend to be more volatile than the percentage growth during the past year, and the latter may thus be a better indicator of current performance of the economy as a whole. The percentage growth during the past year is defined as

\[
GDP_{t-4,t} = 100 \left( \ln GDP_t - \ln GDP_{t-4} \right)
\]  \hspace{1cm} (23)

Estrella and Hardouvelis (1991) used a slightly different approach with the autoregressive component. They use the annualised growth rate within a time-period defined by the forecasting horizon, \( k \). So that in this context it would correspond to \( GDP_{t-k,t} \). They add the autoregressive component only to a regression where they look

\textsuperscript{19} The latest GDP figures are of course subject to future revision, but one can at least get an idea of the current growth rate from those figures. It is also assumed here that the figures from the level of GDP from the turn of the quarter are available at the beginning of the ongoing quarter, even though in reality they are announced with some lag.
at the annualised cumulative change in GNP, whereas in this thesis it is used as a predictor also in a regression considering the annualised marginal change in GDP. It does not seem reasonable to see how the economy grew from a past quarter to another past quarter, and study whether it corresponds to the growth rate from a future quarter to another future quarter, or not. The augmented model specifications for annualised cumulative and marginal change in GDP are

\[ GDP_{t,t+k} = \frac{400}{k} (\ln GDP_{t+k} - \ln GDP_t) = \delta_0 + \delta_1 GDP_{t-4,t} + \alpha_1 SPREAD_t + \epsilon_t \] (24)

and

\[ GDP_{t+k-j,t+k} = \frac{400}{j} (\ln GDP_{t+k} - \ln GDP_{t+k-j}) = \varphi_0 + \varphi_1 GDP_{t-4,t} + \beta_1 SPREAD_t + \eta_t \] (25)

respectively. The regression results for the annualised cumulative change in GDP are presented in table 5.

\[
GDP_{t,t+k} = \frac{400}{k} (\ln GDP_{t+k} - \ln GDP_t) = \delta_0 + \delta_1 GDP_{t-4,t} + \alpha_1 SPREAD_t + \epsilon_t
\]

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<th>(\alpha_1)</th>
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Table 5: Regression results for the cumulative change in GDP. Sample period 1987:1 – 2011:1. Newey and West (1987) adjusted standard errors are inside the brackets. Significance codes: 0.10’, 0.05*, 0.01** and 0.001***. \(\bar{R}^2\) is the adjusted coefficient of determination and SER is the standard error of the regression.
With the addition of contemporaneous growth rate the yield spread remains a significant predictor at all forecasting horizons. However, the current growth rate is also a significant predictor for up to one year in to the future, and the coefficient of the yield spread is smaller than with the model specification (21), where current growth rate was excluded, as expected given the persistence in the growth series’. The model specification (24) is also able to explain more of the variation in the dependent variable for up to one year in to the future, which after the current growth rate is no longer significant. The standard error of the regression is also smaller than with (21) at almost all forecasting horizons, meaning that (24) fits the data slightly better. The regression results for model specification (25) can be seen from table 6.

\[ GDP_{t+k-j,t+k} = \frac{400}{j} \left( \ln GDP_{t+k} - \ln GDP_{t+k-j} \right) = \varphi_0 + \varphi_1 GDP_{t-4,t} + \beta_1 SPREAD_t + u_t \]

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<th>( \varphi_1 )</th>
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<td>1.24***</td>
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<td>(0.13)</td>
<td>(0.58)</td>
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<td>(1.22)</td>
<td>(0.28)</td>
<td>(0.67)</td>
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</tr>
<tr>
<td>k=8, j=2</td>
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<td>1.40</td>
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<td>1.47*</td>
<td>0.20</td>
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<td>(0.32)</td>
<td>(0.59)</td>
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<td>k=12, j=4</td>
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<td>1.74</td>
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<td>(0.40)</td>
<td>(0.72)</td>
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Table 6: Regression results for the marginal change in GDP. Sample period 1987:1 – 2011:1. Newey and West (1987) adjusted standard errors are inside the brackets. Significance codes: 0.10’, 0.05*, 0.01** and 0.001***. \( R^2 \) is the adjusted coefficient of determination and SER is the standard error of the regression.
Also here the coefficient of the yield spread is significant at all forecasting horizons. It is also somewhat larger with $k=8,12$ than with the model specification (22), where the current GDP growth was omitted. However, the coefficient of current growth turns negative after six quarters into the future, so that the larger coefficient of the yield spread compensates for it and the net effect is actually negligible. Still, the model specification (25) is able to predict about twice as much of the variation in the dependent variable compared to (22) with the long forecasting horizons.

The residuals of the model specifications (21), (22), (24) and (25) in the time period from 1987:1 to 2011:1 are all autocorrelated according to the Ljung-Box test, except for (24) and (25) when the forecasting horizon is one quarter (the model specifications are also equal when $k=1$, as mentioned above). This means that if the model over- or underestimates growth during some period, then it will do so also during the next few periods. This is understandable given the rapid growth periods of the late 1980’s and the middle 2000’s, and also the sharp and prolonged contraction of the early 1990’s.

The issues concerning possible autocorrelation in the residuals were left unreported for example in Estrella and Hardouvelis (1991), which makes a thorough comparison of the results from Finland difficult.\footnote{They did use robust standard errors in the regressions but the possible underlying reasons for autocorrelated residuals were not discussed.} Disregarding the residual diagnostics, the regression results from Finland with all the model specifications seem to be in line with those of Estrella and Hardouvelis. It must be noted, however, that their sample period was from 1955:2 to 1988:4, basically meaning that their sample ends where the one in this thesis starts. This means that no straightforward comparison can be made regarding how these specifications work in Finland compared to the USA. This remains a subject for further investigation.
6  Summary and Conclusions

This thesis was motivated by the historical ability of the slope of the yield curve to predict subsequent real economic activity and inflation. This relationship has been confirmed by a number of studies since the early 1980s. However, some of these early studies also found that the predictive power of the yield curve has diminished since the mid 1980s in the United States, and also internationally. Interestingly, the OLS models applied in this thesis fitted the Finnish data quite well, even though the latter sample period was from 1987:1 to 2011:1. Contemporary results from different countries were found to be differing, which suggests that the predictive power is not structural, but rather depends on country-specific characteristics. The model proposed by Arturo Estrella (2005) accounts for these structural breaks in the data, by introducing a monetary policy reaction function and an optimisation problem of the central bank, which affect the extent to which the yield curve is a useful predictor of future real activity and the path of inflation.

The estimation of the model proposed by Estrella (2005) might prove difficult in the case of Finland, due to the use of annual data, which leads to the problem of a relatively small sample. However, it serves an explicit theoretical justification for investigating the predictive power of the Finnish yield curve to subsequent domestic output growth.

The main purpose of this thesis was to, first, investigate whether the yield curve contains information about future economic growth in Finland, and second, to briefly explain the concept of the yield curve and some of the theories behind it.

The sample period of the quarterly Finnish GDP data and the two quarterly interest rate data spanned from the first quarter of 1975 to the first quarter of 2011. This sample period is somewhat troublesome in the case of Finland. It contains periods of very different financial market regulatory regimes; the period of heavy regulation from 1975 to late 1980’s and the period of lax regulation from the late 1980’s to present. In addition, there is the high inflation period in the early end of the sample and the period called the Great Moderation, a period of low inflation and stable growth, from the mid
1990’s to the mid 2000’s. Moreover, Finland experienced a severe depression in the beginning of the 1990’s lasting for about three years, and even a steeper decline in 2009, from which the recovery was quite rapid. Finland joined the European Exchange Rate Mechanism (ERM) in 1996, effectively pegging the value of the Finnish mark to a basket of currencies called the European Currency Unit (ECU), which transformed in to the euro in 1999. With the pegging of the national currency, some sovereignty of the Bank of Finland was lost and it was no longer able to set the short term interest rates freely.

All the reasons described above point to the conclusion that there is probably at least one structural brake in the data. No formal statistical test to pin down possible breaks were made, but rather the data was split at 1987:1 due to major changes in the financial market regulatory regime at the time.

As expected, the results from the entire sample period were quite poor, and even with the best specifications the regression models were able to explain less than 10% of the variation in GDP growth. The results from the second period 1987:1 – 2011:1 were more impressive, but strong persistence arising from increasing the forecast horizon suggested that an autoregressive component capturing contemporaneous growth should be added to the regressions. As expected, the autoregressive component had significant predictive power, at least with relatively short forecasting horizons. It was positive with short forecasting horizons and turned negative at long forecasting horizons, especially with the regression trying to predict future marginal changes in GDP. At the same time the coefficient of the yield spread was larger compared to the regression from which the autoregressive component was omitted, indicating a negligible difference in predicted GDP growth given any yield spread.

The results of this thesis lend encouraging support for the ability of the yield curve to predict changes in real GDP in Finland. Including more explanatory variables, or more lagged values of the GDP growth rate, to the regressions remains a subject for further research. The regressions of this thesis also made use only of the spread between a long and a short yield, whereas more information from the yield curve could be extracted by using more differences along the maturity spectrum.
References


European Central Bank. Internet source. www.ecb.int


