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Are there constant risk premia on the Swedish money market?

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Sammanfatting

Titel: Are there constant risk premia on the Swedish money market?

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Fem Nyckelord: Yield curve, avkastningskurva, term structure, rolling down, expectations theory.

Syfte: Uppsatsen undersöker om det genom statistisk och ekonomisk analys går att visa om riskpremierna på den svenska penningmarknaden är konstanta över tiden eller ej. Den har dessutom som sekundärt syfte att analysera vilka faktorer som driver riskpremier.

Slutsats: Det framgår av studien att det går att förutse prediction errors som är skilda från noll. Detta innebär att riskpremierna för långa värdepapper relativt korta värdepapper inte är konstanta över tiden. Inflation, växelkursregim, lutningen på avkastningskurvan och även tiden har dessutom effekt på olika värdepappers riskpremier.

Summary

Title: Are there constant risk premia on the Swedish money market?

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Five Keywords: Yield curve, avkastningskurva, term structure, rolling down, expectations theory.

Purpose: This thesis investigates, through statistical and economical analysis, whether it can be shown that risk premia on the Swedish money market are constant or not. It also means to investigate what factors drive risk premia.

Conclusion: The study shows that it is possible to predict nonzero prediction errors. This means that the risk premium of a long security over a short one is not constant over time. Also, inflation, exchange rate policy, the slope of the yield curve and even time affects the risk premia of different securities.

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1 Introduction

1.1 Background

Much research has been dedicated to the behavior and properties of the yield curve. In a way, the theories of the prices and yields throughout the term structure make a good description of the core of financial theory, in a broad sense, since it captures many important and central aspects of financial economics. Essentially, the yield curve can be described as the yield of government bonds and treasury bills of all available different maturities at a given moment in time. Typically, governments offer securities of a wide range of maturities for potential investors to choose from. However, the yields of these securities are only indirectly controlled by the government (typically through some sort of short-term base rate), and the bonds and bills are bought and sold on the money market, implying the existence of market equilibriums, buy/sell price gaps, and similar open market conditions. The fact that the money market is a "normal" open market is intriguing to economists due to the fact that it means that the yield curve can be said, at least in theory, to include all of the market's expectations of future yield rates. Rates are set based not only on current yields, but also heavily on expected *future* yields. This can be seen in time series patterns of the yield curve. For example, if history is any guide, we can expect a rather sharp decrease in short rates whenever the long rate is lower than the short rate, and so on.

Some investors make money through the process of "rolling down". This represents the fall in a bond's yield as it approaches its maturity. Correspondingly, when a bond's yield falls, its price rises. This fact is exploited by investors to make money. Pairing, for example, a two-year bond with a one-year treasury bill, it is possible to make the difference in yield as a *roll down opportunity*. Leveraging these investments provides actual money making opportunities[1]. However, these opportunities rely on expectations and a belief in long bonds providing higher yields than short ones, a so-called risk premium. Hence the roll down strategy is not optimal in all circumstances. How do expectations and risk premia correspond to each other?

1 Wall Street Journal, European edition, 2004-04-21.

The fact that the yield is usually upward sloping - the fact that there is a risk premium - is an absolute requirement for investors wishing to take advantage of rolling down opportunities. But is the risk premium reliable? The expectations theory of the yield curve assume that risk premia are constant over time. But is this really the case? Fama (1984) shows how risk premia of forward exchange rates vary greatly over time, so why should risk premia on bonds be any different?

1.2 Problem statement

Typically, the yield curve can be said to be upward sloping. This means that yields on long bonds usually are higher than short rates, on a yearly basis. This fact has generally been explained by economists as the effect of a market *risk premium* that investors demand due to interest rate risk, or a so-called liquidity preference. The existence of such a market premium would have certain implications for investors working primarily in the money market.

The expectations hypothesis of the yield curve (henceforth referred to as ET) states that long bonds on average will give the same yield as a series of short bonds covering the same maturity, *plus* a risk premium. This risk premium is taken to be constant over time. This implies that if we know the premium, and the one-year and two-year yields today, we can calculate the expected one-year yield a year from now. This is the ET prediction.

The rational expectations hypothesis[2] states that such expectations that are "informed" and rely on relevant economic theory are "rational expectations" (henceforth referred to as RE). "Informed" in this case means that there is market efficiency. Here, this implies that if ET is assumed to be correct (and thus constitutes a "relevant economic theory"), then rational expectations are those that are given by the ET. By calculating the expected yield, we therefore have the market's rational expectations of future yield. How does this expected yield correspond with the actual future yield?

If the market is efficient, and has rational expectations, the average of all expectations should be distributed around the prediction of the theory *if the expectations theory is correct*. If we assume that the market holds all available and relevant information, we can test if there are

2 Muth, J, p. 316.

any consistent prediction errors in the markets. Are the market's expectations on average right, or are they consistently too high or too low? Are errors randomly distributed? Do they depend on any macroeconomic factors, and is there a time trend?

If any such consistent errors exist, we know that our assumptions cannot be true when combined with the notion of constant risk premia. This is because such anomalies would be adjusted by the market, and thus would not stay at the level which our assumptions predict[3]. Therefore, we make analysis to see whether prediction errors from constant risk premia can be predicted from the information set, the relevant pieces of available information at the time. If so, we must conclude that risk premia are *not* constant.

The interest of this thesis is thus to investigate whether, given certain assumption, risk premia of long bonds over shorter ones are constant over time. This is done by seeing if errors from prediction of the ET can to some extent be forecasted by some variables at the time of prediction. If so, then risk premia can not be constant, given our assumptions. Why is this of any interest for us? First of all, speculators of rolling down opportunities may find it intriguing, as mentioned above. But even more interestingly, understanding risk premia is a way of understanding the way the market forms expectations, and under what circumstances it is more cautious or risk-taking, and so on. This is interesting to anyone involved in the field of macroeconomics or financial economics. For example, central banks may find the results interesting, as well as any bank working with estimating and forecasting expectations, and so on.

1.3 Aim

The interest of this thesis is to investigate, for the Swedish money market, whether the risk premia of long bonds over shorter ones, is constant over time or not, and if the risk premium is affected by any macroeconomic factors.

3 Nicholson, p. 477

1.4 Target group

This thesis is directed mainly at students at Lund University, but the results should hopefully also be of some interest to economic researchers and policy makers, as well as investors on the money market, and anyone else that would gain from information regarding how the market shapes expectations about future interest rates and values different securities.

1.5 Statement of definitions

In this thesis I've chosen to focus on the Swedish money market. The reason why I chose to analyse Sweden is that the gathering of data was relatively straightforward and also that I found it interesting to focus on my own country. Sweden also executed a change in monetary policy regime in 1992, and I wanted to analyse if this fact that had any impact on the results. Finally, Sweden has an "open" policy central bank, as opposed to the European central bank or the Federal Reserve, for example, and I found it compelling to study market expectations in this financial climate.

I've gathered data from 1983 to 2004. I've gathered data of Swedish t-bills of 1 to 12 months' maturity and government bonds of 1 to 10 years' maturity. I'd like to thank the Swedish central bank for providing all the historical yield data. All data are closing-time quotes. Also, I have received CPI data from the EcoWin database.

2 Method

2.1 Quantitative and qualitative methods

In the scientific community, there is a distinction between *qualitative* and *quantitative* studies. These are the two main types of scientific studies.

The *quantitative* approach takes into account a large number of observations or study objects, measuring and quantifying the data in question. This data is then used in quantitative tests of a standardized and generally accepted form, usually involving statistical or other similar methods. This gives comparativeness to the study, making analogies with similar studies more relevant. It also gives reliability to the results. A downside of this approach is a risk of not detecting less obvious contexts or causes. This sometimes makes the quantitative a poor choice for deductive studies (see below).

The *qualitative* approach, on the other hand is characterized by taking a small number of observed objects into consideration, but performs a deeper analysis with these than that of the quantitative approach, subtracting a lot of information about every object. This enables deeper conclusions to be made, that maybe would not have appeared in a quantitative study. A drawback, however, is that these conclusions are more sensitive to the bias of the researcher, since it is harder to reject an idea, i.e. to prove it wrong using the qualitative approach. Also, due to the fact that it's based on fewer observations, it has lower power than the quantitative approach for generalizing any findings to a broader perspective. In conclusion, neither approach can be said to be "better" than the other: They are used in different contexts, they both have limitations, and they should be thought of as complements to each other[4].

This study is about testing an economic theory assuming the validity of other economic theory. I use a lot of data to perform this test. Clearly, the choice must be the *quantitative* approach.

4 Holme, et al, p. 14, 157

2.2 Inductive and deductive methods

What the quantitative and quantitative concepts are to the practical method of a study, the deductive and inductive concepts are to the shaping of a scientific theory in the study.
The inductive approach, or "the path of discovery", focuses on the specific object of interest, shaping a theory from this that is meant to be generally valid. Another way of putting it is calling it a "specific to general" approach.

The deductive approach, on the other hand, is characterized by starting with forming a theory that is used to draw conclusions regarding specific objects. Also called "the path of proof", this approach uses established theories of the object of interest and then performs empirical tests of the hypotheses of these theories. Hence, it is the chosen theory that determines what data needs to be gathered, how it should be interpreted and its relation to the theory. This could also be called a "general to specific" approach.

This thesis means to test assumptions of earlier theories. Clearly, it is a deductive study.

2.3 Primary and secondary data

In any study two types of data can be used: Primary and secondary data. Primary data is data which is gathered first-hand for the study, such as an interview, whereas secondary data is gathered before-hand by others, i.e. books or databases.

The data that I require for this thesis is mainly yield curve historical data, which is supplied by the Swedish central bank. In other words, we are dealing with secondary data.

2.4 Critical review of the data

While analysing the data to see whether it is of high or low quality, one should take into account four different criteria of data quality. These criteria are: Observation, origin, interpretation and usability[5].

5 Ibid p. 130

2.4.1 Observation

The first criterion states that the actual process of data collecting must be properly coordinated. Is it possible that the researcher has failed to use similar data also available somewhere else? Similarly, redundant data should be excluded. All my data has been gathered from the Swedish central bank. This is a professional government institution, and thus the risk of such collection errors is low. However, there are gaps in the data, albeit not to the extent that it affects reliability.

2.4.2 Origin

This criterion focuses on the origin of the data. Why was the data gathered, and how does this affect the reliability and credibility of the data?

The Swedish central bank would have nothing to gain by providing flawed data and therefore we have no reason to suspect any such flaws. Hence there are, in my opinion, no origin-related problems with the data.

2.4.3 Interpretation

The interpretation criterion states that the source must be interpreted based on the circumstances around the date of the collection of the data. Do these circumstances affect the intentions of the data collector?

In this case, this criterion hardly applies. The type of data is such that it is not in danger of any such arbitrary influence from the data collector, and thus we do not need to worry about errors of this sort.

2.4.4 Usefulness

Finally, an important criterion is usefulness. Does the data describe what it intends to describe? There is a distinction between internal and external credibility.

- External credibility is given by comparison with similar sources. If the data is similar, this enhances credibility. In the case of this study, the data is provided by such a well-trusted institution and therefore I have chosen to not bother with not trusting the data.
- Internal credibility is determined by consistency, security, understanding and unbiasedness[6]. The Swedish central bank excels in these areas, and they are central to its credibility and day-to-day operation. Thus I have no suspicions of problems in this case either. However, one should be aware that statistical databases are maintained by humans being, and human beings – being imperfect by nature – are prone to make mistakes. But I feel confident that the sheer amount of data will make all effect of any such errors not make any difference.

2.5 Reliability

Reliability can be described as the trustworthiness of the execution of the study. It relies heavily on how thoroughly information is processed. One way of enhancing reliability is using different methods for the measurement of crucial information. So long as these methods produce similar results, we can be sure of the accuracy of our measurements. Furthermore, attention to detail and avoiding errors is of utmost importance throughout the scientific process in order to achieve high reliability.

The reliability in this thesis gains from my use of many different series of yields, and my thorough statistical analysis. Also, as will be discussed later, I'm using different approximations of the risk premium in order to make a benchmark for comparison of my results. Finally, the large amount of observations provides high reliability for my statistical analysis.

6 Ibid s. 135-136

2.6 Validity

A frequently occurring problem in scientific studies is a lack of closeness to the object being studied. This means that the object in question cannot be observed in detail, resulting in a problem of validity or legitimacy since the scientist fails to take into account some hidden context[7].

The validity criterion considers how well the method manages to measure what it means to measure. If one does not manage to accurately measure, there is a risk of overlooking plausible solutions or explanations. In other words, it is important to make sure all reasoning behind the work method is clear, convincing and rigorous so there are no "holes" to allow for validity problems. In this context, it is crucial to clarify all assumptions and theoretical definitions. Excluding alternative theories or explanations must be motivated.

Since the purpose of this thesis can be conceived as somewhat abstract, there is a risk of a validity problem as addressed above, unless I manage to clearly explain my reasoning. For this reason, I have devoted an entire chapter, chapter 6, to the assumptions and context of the theoretical issues presented in the thesis. This chapter is written in addition to the theoretical concepts chapter, because the context of all the isolated theories is as important as the theories themselves. There, the validity of the thesis is discussed more thoroughly and I hope that this will help avoid any misconceptions. Also, the reasoning of the thesis is based in part on Fama (1984). I've added a section explaining briefly the discourse, methodology and findings of this article, which may also prove helpful.

7 Huberman, M – Miles, M, 1994. *Qualitative data analysis.*

3 Theoretical concepts

3.1 Calculating yield on yearly, quarterly or monthly basis

For this thesis, I'm using the internationally accepted model for calculating the yield of a financial asset for any basis, whether it's a year, a month and so on. It is written

$$Yield = 1 + r\left(\frac{ACT}{BAS}\right) \qquad \text{(Equation 1)}$$

where r is the percent yield on a one-year basis, ACT is the actual number of days (that is, the maturity of the security) and BAS is the number of days in the "yield base" that the country in question utilizes. For Sweden and the US, this is 360 days, whereas in the case of the UK, it is 365 days etc. The reason for the base not always being 365 days is that the actual number of days during a six-month period may vary, and different countries choose different ways of solving this problem. Consequently, the yield of a Swedish three-month treasury bill equals[8]:

$$Yield = 1 + r\left(\frac{90}{360}\right) = 1 + r\left(\frac{3}{12}\right) = 1 + r \cdot 0{,}25 \qquad \text{(Equation 2)}$$

3.2 Essential bond pricing, zero rates and the "bootstrap" method

The pricing of a bond is straightforward, since it involves only secure future payments, at least ideally, and certainly in the case of government securities, where the default risk can be seen as practically zero. The proper price of the bonds is obtained by discounting these payments using an appropriate so-called zero rate for each payment. The *n*-year zero rate is simply an interest rate that provides all interest and principal after *n* years. Thus, unlike a bond, the zero rate represents an investment without any intermediary payments or coupons, much like a t-bill, only also covering longer time periods than t-bills usually do. With the appropriate zero rates, r_t, at hand one can calculate the price of a bond as

8 Hässel, et al p. 32.

$$P_t = \sum_{t=1}^{n} CF_t \cdot e^{-t \cdot r_t} \qquad \text{(Equation 3)}$$

that is, simply the sum of cash flows discounted by their respective zero rate. In practice, the obtainment of the zero rate can prove a larger problem. I will use the so-called bootstrap method to calculate zero rates. Let's say we want to know the zero rate of a two-year bond. The zero rate of the coupon received after one year is equal to the one-year t-bill rate, which we assume that we already know. Thus we discount the value of the coupon, and subtract this from the price of the bond, in effect calculating the price of a two-year zero-coupon bond. We can now calculate the two-year zero rate, as it is implied by the price and principal that we have calculated. And thus, as we now have the two-year zero rate, we can calculate the three-year zero rate from a three-year bond in the same manner, and so on[9]. Assuming annual compounding and setting the price of the bond equal to 100, we can generalize the expression in the following equation:

$$R_n = \left(\frac{100 + CF_n}{100 - \sum_{i=1}^{n-1} \frac{CF_n}{(1 + R_i)^i}} \right)^{\frac{1}{n}} - 1 \qquad \forall n \geq 2 \qquad \text{(Equation 4)}$$

In this paper, I will use zero rates to value long bonds after a year, or more, has passed in order to calculate rolling down earnings. Bonds are reported in yearly cash flows, and therefore need to be recalculated to the zero rates.

3.3 The efficient market hypothesis

One of the assumptions of my thesis is that of efficient markets, the efficient market hypothesis (EMH). This theory is the foundation of correct valuation. An efficient market is characterised by the price of a security (and thereby the yield) reflecting all available information relevant for the security[10]. The EMH states that predicting a price movement on the market should on average not be possible.

9 Hull, J, p. 91.

10 Fama, (1991), p. 1575

A market is said to be efficient if there are no possibilities of abnormal or increased yield by using any type of publicly available information. When new information enters the market, the market reacts immediately. However, in reality, different types of information affect prices in different ways, and for this reason the EMH is divided into three types of EMH, based on the type of information that affects prices[11].

1. Weak form – Historical prices are reflected in the prices
2. Semi-strong form – All publicly available information is reflected in the prices
3. Strong form – All information, including insider information, is reflected in the prices[12].

3.4 Rational expectations

The concept of rational expectations was introduced by Muth (1961). Essentially, Muth defines rational expectations (RE) as “informed predictions of future events, (…) the same as the predictions of the relevant economic theory”[13]. In other words, a rational expectation of a future price, for example, is simply the informed and theoretical calculation of that price. Muth does point out, however, that it is the *aggregate* expectations that are rational in this sense, and not necessarily the expectations of an individual entrepreneur.

Muth also makes some definitions which are of special interest later. These are:

1. The random disturbances are normally distributed.
2. Certainty equivalents exist for the variables to be predicted.
3. The equations of the system, including the expectations formulas, are linear[14].

We will discuss this more in chapter 6, and also conclude that assumptions 2 and 3 do not apply in our case. However assumption 1 does apply. Muth states that the three assumptions practically imply each other[15].

11 Ross, et al p. 343
12 Ibid, s.343-347
13 Muth, s. 316
14 Ross, et al p. 317
15 Ibid, s. 317

3.5 The expectations hypothesizes of the term structure

The term structure of interest rates, often referred to as the "yield curve" is for any point in time simply the set of available yields of government bonds and treasury bills. The central theory of this thesis, the expectations hypothesis of the term structure, is the most central school of thought for how expectations of future yields of government securities are formed. There is a distinction between two forms of the hypothesis: The expectations hypothesis (we shall also refer to it as the "standard" expectations hypothesis) and the *pure* expectations hypothesis[16].

3.5.1 Pure expectations hypothesis

The pure form of the expectations theory (PET) states that over a given time period, short and long bonds are expected to give the same yield. That is, no excess returns are expected for a long bond compared to a sequence of consecutive short bonds spanning the same maturity. This can be written mathematically as[17]

$$(1+y_{nt})^{n} = (1+y_{mt})^{m} E_t(1+y_{m-n,t+m})^{n-m} \qquad \text{(Equation 5)}$$

or, equivalently,

$$E_t(y_{m-n,t+m}) = \left[\frac{(1+y_{nt})^{n}}{(1+y_{mt})^{m}}\right]^{\frac{1}{n-m}} - 1 \qquad \text{(Equation 6)}$$

This simply states that the yield of an *n*-period bonds is equal to the expected yield of a combination of a *m*-period and an *(n-m)*-period bond[18], *n* and *m* being positive and $n > m$.

This means that we can make estimates of future yield rates. For example, if short rates are higher than long rates, the PEH implies that we can expect a decline in short rates. Simply looking at a graph of historical short and long yields will confirm this notion; Most of the

16 Campbell, et al, p. 413

17 Campbell, et al. p 413 and Hässel, et al. p 102

18 "Yield", unless otherwise stated, refers to *zero yield*. Consequently, in most cases the word "bond" in this section could be replaced by the word "T-bill".

time when short rates are above long rates, the short rate will fall. For an example of this, consider graph A.1 in the appendix.

3.5.2 Expectations hypothesis

The pure expectations hypothesis is a important theory of explaining bond pricing and specifically predicting price movements. However it does not always act in accordance with reality. Let's say that the two-year yield is higher than the one-year yield. The PEH would indicate in this case the expectation of a rise in the one-year rate above the two-year rate, within a year (in order for the yield of the two-year bond to be the same as the yield of two one-year bonds). But historically, this finds no support in reality since short rates are in fact usually *persistently lower* than long rates, only occasionally rising above longer rates. This can be seen easily by looking at any set of historical yield data, including the Swedish rates I'm using in this study (see graph A.1).

A more realistic version, perhaps, that would hopefully eliminate the clearly empirically faulty conclusion above, is the expectations theory (ET). The expectations hypothesis is a different form of the pure expectations hypothesis, allowing for constant differences in expected yield between bonds[19]. In other words, this theory states that a long bond does *not* give the same yield as a series of short bonds, but that the expected deviation is constant over time. This makes sense in an empirical perspective, since longer bonds do, on average, give higher yield which can be seen in any historical graph of yield curves. Thus we make an alteration of equation 5, allowing for constant deviations between a given short rate and a given long rate. This deviation is called the *risk premium*. If we define the risk premium of a *x*-period bond over a *y*-period bond as Φ_{xy}, we can write the EH relationship as

$$(1+y_{nt})^n = (1+y_{mt})^m E_t(1+y_{m-n,t+m}+\Phi_{n,n-m})^{n-m} \qquad \text{(Equation 7)}$$

or, equivalently,

19 Campbell, et al. p. 415

$$E_t\left(y_{m-n,t+m}\right)=\left(\frac{\left(1+y_{nt}\right)^n}{\left(1+y_{mt}\right)^m}\right)^{\frac{1}{n-m}}-\left(1+\Phi_{n,n-m}\right). \qquad \text{(Equation 8)}$$

Definition and calculations of the risk premia for this thesis are discussed in section 6.4.2.

3.5.3 Liquidity preference theory

Is there a reason why long rates seem to be persistently higher than low rates? A theory that means to explain this phenomenon is the liquidity preference theory. This states that investors generally are risk averse and prefer short maturities. In other words they have a short investment horizon, and do not wish their capital to be tied up for a long time period. Longer bonds are less popular and for this reason, they have lower price, i.e. a higher yield. This higher yield can be called the “risk premium” of long bonds. This risk was addressed in the previous section, and is the reason why the yield curve is usually upward sloping.

4 Statistical and practical methods

4.1 Data processing

The data contained some gaps, which were filled in with the latest entry. Once the daily data was completed this way, zero rates were calculated from the data. Next, all treasury bill yields were sorted so that the all “future” yields 1, 2 etc. even up to 12 months ahead were paired with today’s date. This way, today’s one-month rate could easily be compared with the one-month rate in one month time, or any other combination, for that matter. The corresponding action was performed for the bond data, providing new time series of all bond yields 1, 2 up to 10 years from the sell date. These actions were performed in order to have a benchmark for the estimated expectations. This analysis is discussed in section 6.4.6.

4.2 Statistical significance through the student’s t-test

When working with numerical data, it is common to calculate statistical parameters of the data, such as mean and standard deviation. These, of course, measure the average value of a variable and the average deviation from that value, respectively. Often, when enough observations are at hand, a series can be approximated as *normally distributed*. This means it follows a “bell-shaped”, symmetric probability distribution. Defining the sample mean and sample standard deviation as $\bar{x}$ and s, this approximation means that 68.26 % of the population is assumed to be found within $\bar{x} \pm s$, and 95.44 % within $\bar{x} \pm 2s$, etc[20]. These intervals are called confidence intervals.

This has implications for statistical analysis, because we can test whether or not a variable’s true mean can be expected to be found within a given interval, or rather, calculate the probability that it is. When testing if the mean is higher or lower than a given value, this is done using the equation[21]

$$t = \frac{\bar{x} - \mu_0}{s/\sqrt{n}} \qquad \text{(Ekvation 9)}$$

20 Lee, et al.

21 Lee, et al. p. 457-8

where μ_0 is the given value. Alternatively, one could test if the means of two variables are equal using the formula

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1}{n_1} + \frac{s_2}{n_2}}} \qquad \text{(Ekvation 10)}$$

The value *t* is compared to a modified version of the table of the normal distribution, called the student's *t* distribution. This distribution has thicker tails the less observations, *n*, there are in the sample, in effect making the confidence intervals broader and less specific or "secure".

4.3 Time series analysis with the ARMA model

The ARMA model means to capture reoccurring patterns in time series movements. It is a model commonly associated with estimation and forecasting of time series analysis. Essentially, it is made up of two models: The autoregressive process, AR, and the moving average process, MA.

4.3.1 AR – The autoregressive process

It is reasonable to view some time series as following a relatively steady path. For example, we do not imagine that a 3 % yield will be followed by a rate of 112 % for example. Rates move more smoothly than that. Of course, jumps and sudden shifts *do* occur, for instance the 500 % overnight rate accompanying the 1992 defence of the Krona[22]. But the market yields, on the other hand, did not absorb too much of this exceptionally high rate. Bond yield time series seem to have a "built-in shock absorber", preventing extreme movements, and in return the effects linger well after the initial shock is gone. This is the statistical explanation. In reality, of course, the 500 % rate was not credible, and therefore market yields failed to adjust in correspondence.

22 Blanchard, p. 446

In statistical terms, again, the absorber could be called the autoregressive component, AR. A simple time series with an AR component could be written as[23]

$$y_t = \phi y_{t-1} + \varepsilon_t \qquad \text{(Equation 11)}$$

where ϕ is a coefficient, usually $0 < \phi < 1$, and ε_t is an error term. This is called an AR(1) process. This, of course can be generalized as an AR(p)[24]:

$$y_t = \phi_1 y_{t-1} + \ldots + \phi_p y_{t-p} + \varepsilon_t \qquad \text{(Equation 12)}$$

This can of course be estimated through regression analysis.

4.3.2 MA – The moving average process

A moving average process indicates that there is a lagged connection between residuals and level. In other words, errors do not immediately disappear but rather linger for a while. This is indeed plausible in reality; If markets yields were to be somehow affected suddenly, it would take a little time before the levels returned to “normal”. This was the case, again, when the overnight rate was raised to 500 %. This high rate, of course, was not credible in the long term and was dropped. The short market yields never reached this high level, due to the lack of credibility, and it took a few days before they were down to around their previous level. This could be viewed as an MA process and the sudden high rate as a large positive error, ε_t. We can express the MA(1) process as[25]

$$\begin{aligned} y_t &= \varepsilon_t + \theta \varepsilon_{t-1} \\ &= \varepsilon_t + \sum_{i=1}^{q} \theta_q \varepsilon_{t-q} \end{aligned} \qquad \text{(Equation 13)}$$

Assuming $y_0 = 0$, It is also possible to express an AR(1) process as a MA(∞) process as[26]:

23 Campbell, et al

24 Ibid.

25 Ibid.

26 Ibid.

$$
\begin{aligned}
y_t &= \phi y_{t-1} + \varepsilon_t \\
&= \phi(\phi y_{t-2} + \varepsilon_{t-1}) + \varepsilon_t \\
&= \sum_{j=0}^{\infty} \phi^j \varepsilon_{t-j}
\end{aligned}
\qquad \text{(Equation 14)}
$$

Finally, the two processes can be combined to a so-called ARMA(*p,q*) process as[27]:

$$
y_t = \phi_1 y_{t-1} + \ldots + \phi_p y_{t-p} + \varepsilon_t + \theta_1 \varepsilon_{t-1} + \ldots + \theta_q \varepsilon_{t-q} \qquad \text{(Equation 15)}
$$

4.4 Autocorrelation and non-stationarity in time series

An important concept in time series analysis is autocorrelation. The goodness-of-fit provided by the ARMA model is determined by certain properties of the empirical data observed. In other words, autocorrelation plays a major part. Autocorrelation is analogous to ordinary correlation; however it measures the correlation between a series and its *lag*, rather than between two series. Mathematically, this is expressed as[28]

$$
\rho_k = \frac{Cov[y_t, y_{t-k}]}{\sqrt{Var[y_t] Var[y_{t-k}]}} = \frac{\gamma_k}{\gamma_0} \qquad \text{(Equation 16)}
$$

where, for $k = 1$,

(Equation 17)

$$
\gamma_1 = E[(y_t - \mu)(y_{t-1} - \mu)] = E[\phi_1 (y_{t-1} - \mu)(y_{t-1} - \mu)] + E[\varepsilon_t (y_{t-1} - \mu)] = \phi_1 \gamma_0 ,
$$

implying that for an AR(1) process we have[29]

$$
\rho_k = \frac{\phi_1 \gamma_0}{\gamma_0} = \phi_1 . \qquad \text{(Equation 18)}
$$

When performing regression analysis, it is crucial that the series being used are stationary. It is also sometimes of interest for other reasons. Stationarity means that the mean of the series

27 Ibid

28 Franses, p. 42-43

29 Franses, p. 43.

needs to be constant over time, and that the autocorrelation depends only on *k*, not on *t*. These conditions are expressed as[30]

$$E(y_t) = \mu$$
$$\mathrm{var}(y_t) = \sigma^2 \qquad \text{(Equation 19)}$$
$$\mathrm{cov}(y_t, y_{t+k}) = \mathrm{cov}(y_t, y_{t-k}) = \gamma_s$$

However, these conditions are rarely met in financial time series. For example, a quick look at graph A.1 will definitely not indicate any constant mean of bond yields. A time series with a constant mean is called a "mean-reverting" series. In MA(1) terms, this implies $\phi < 1$ in the process[31]

$$y_t = \alpha + \phi\varepsilon_{t-1} + \varepsilon_t \qquad \text{(Equation 20)}$$

If $\phi = 1$, we have a so called "random walk", meaning the level and average of the series meanders randomly, much like many financial time series. This is also called a series with a "unit root". If $\phi > 1$, the series has an explosive path of expansion. However this is very implausible and in reality, such a series hardly exists, at least not in the world of financial economics[32].

4.5 The Dickey-Fuller test of unit root

Consequently, we need to know whether or not a series have a unit root. We want to test whether $\phi = 1$ in the regression

$$Y_t = \delta + \phi Y_{t-1} + \varepsilon_t\,. \qquad \text{(Equation 21)}$$

One might be led to believe that a simple *t*-test would suffice, but alas things are more complicated than that. As Dickey and Fuller (1979) showed, the regression above does *not* follow a *t*-distribution if the null hypothesis is true, not even asymptotically (that is, when the number of observations becomes very large). The reason for this is that the non-stationarity

30 Hill, et al p. 336.

31 Hill, et al p. 338.

32 Hamilton, p. 544

interferes with the inference of the regression. The solution is given by adjusting the critical *t*-values and calculating the test value as

$$DF = \frac{\hat{\phi} - 1}{se(\hat{\phi})} \qquad \text{(Equation 22)}$$

This value is compared to the adjusted critical *t*-values, the so-called DF-values. However, because of the adjustment, the test now has far lower power than a *t*-test. For example, the -1.65 critical value of the *t*-test corresponds to -2.86 for the Dickey-Fuller test. This means that a lot more observations are needed to reject the null of unit root[33].

Furthermore, it should be noted that the random walk can also be present in models with more lags, a constant (as above) or none, and a time trend. Corresponding versions of the Dickey-Fuller test are available, so-called *Augmented* Dickey-Fuller (ADF). However, the general idea is the same and the method of testing is similar.

4.6 Multicolinearity in regression analysis

Multicolinearity is defined as when two variables in a regression make up an approximate linear relationship. This can often lead to unreliable regression estimates[34]. One or more parameters could be highly inaccurately estimated. This can be the case, for example, when using two variables that follow each other tightly. For example, interest rates of close maturities may display this problem.

One solution is, of course, omitting one of the problematic variables. Another is to extend the sample size[35]. A third solution, which is of course not always practical, is to make a linear combination of the variables that holds some degree of interpretability, such as the difference between them or something similar. For this reason, I've taken the difference of two yields as independent variables in my regressions, rather than the yields themselves separately.

33 Verbeek, p. 269.

34 Verbeek p. 42

35 Ibid p. 43

5 Previous studies

5.1 Fama, Eugene F – "Forward and spot exchange rates"

Fama (1984) addresses the issue of risk premia for forward exchange rates. There are unobservable expectations and risk premia for these, just like the case with the yield curve, which makes it a good analogy for my study. Fama addresses the problem of trying to estimate these variables and observing their existence. He concludes that the forward price is the markets security equivalent.

Fama noticed that many studies could not reject the null $\beta = 1$ of in

$$S_{t+1} - S_t = \alpha + \beta(F_t - S_t) + \varepsilon_{t+1}.$$

where S_t is the spot exchange rate and F_t is the forward exchange rate. He makes the assumption of rational expectations and efficient markets, in order to make conclusions regarding the risk preferences of investors. He also assumes disturbances to be independently and identically distributed. Furthermore Fama makes the assumption of a *variable* risk premium.

From a rewritten form of the equation above, Fama makes the equivalent regressions

$$F_t - S_{t+1} = \alpha_1 + \beta_1(F_t - S_t) + \varepsilon_{1,t+1}$$
$$S_{t+1} - S_t = \alpha_2 + \beta_2(F_t - S_t) + \varepsilon_{2,t+1}$$

Where $\beta_1 + \beta_2 = 1$ och $\alpha_1 + \alpha_2 = 0$. Now, since

$$\beta_1 = \frac{\operatorname{cov}(F_t - S_{t+1}; F_t - S_t)}{\operatorname{var}(F_t - S_t)} \text{ and } \beta_2 = \frac{\operatorname{cov}(S_{t+1} - S_t; F_t - S_t)}{\operatorname{var}(F_t - S_t)}$$

we can make the definitions

$$\beta_1 = \frac{\operatorname{cov}(\varepsilon_{t+1};P_t) + \operatorname{cov}(\varepsilon_{t+1};E(S_{t+1}-S_t)) + \operatorname{var}(P_t) + \operatorname{cov}(P_t;E(S_{t+1}-S_t))}{\operatorname{var}(P_t) + \operatorname{var}(E(S_{t+1}-S_t)) + 2\operatorname{cov}(P_t;E(S_{t+1}-S_t))}$$

and

$$\beta_2 = \frac{\operatorname{cov}(\varepsilon_{t+1};E(S_{t+1}-S_t)) + \operatorname{cov}(\varepsilon_{t+1};P_t) + \operatorname{var}(E(S_{t+1}-S_t)) + \operatorname{cov}(P_t;E(S_{t+1}-S_t))}{\operatorname{var}(P_t) + \operatorname{var}(E(S_{t+1}-S_t)) + 2\operatorname{cov}(P_t;E(S_{t+1}-S_t))}.$$

But the assumption of rational assumptions and uncorrelated errors, removes the terms $\operatorname{cov}(\varepsilon_{t+1};P_t)$, $\operatorname{cov}(\varepsilon_{t+1};E(S_{t+1}-S_t))$, $\operatorname{cov}(\varepsilon_{t+1};E(S_{t+1}-S_t))$ and $\operatorname{cov}(\varepsilon_{t+1};P_t)$, and we are left with

$$\beta_1 = \frac{\operatorname{var}(P_t) + \operatorname{cov}(P_t;E(S_{t+1}-S_t))}{\operatorname{var}(P_t) + \operatorname{var}(E(S_{t+1}-S_t)) + 2\operatorname{cov}(P_t;E(S_{t+1}-S_t))}$$

and

$$\beta_2 = \frac{\operatorname{var}(E(S_{t+1}-S_t)) + \operatorname{cov}(P_t;E(S_{t+1}-S_t))}{\operatorname{var}(P_t) + \operatorname{var}(E(S_{t+1}-S_t)) + 2\operatorname{cov}(P_t;E(S_{t+1}-S_t))}.$$

This means that, since $\operatorname{var}(E(S_{t+1}-S_t))$ is always positive, a negative β_2 implies not only that $\operatorname{cov}(P_t;E(S_{t+1}-S_t))$ is non-zero (negative), it is also larger in magnitude than $\operatorname{var}(E(S_{t+1}-S_t))$. This is what Fama found, and thus the premium is not constant. The specific method of his study is not relevant for this thesis, but the assumptions are very suitable.

6 Assumptions and theoretical context

6.1 Context of assumptions

In order to clarify the train of thought this thesis, this chapter is dedicated to presenting the assumptions and the way they connect. A lot of the terminology is analogous with Fama (1984). The context of the thesis is briefly presented and discussed in this section, and in the following sections the assumptions are discussed. This is followed by a thorough discussion of the test method and hypothesis of the thesis.

Let's say that we were to assume perfect validity of RE, ET, EMH and constant risk premia (equal to the average yield spread over time). This would imply that a well informed market would expect future yield in complete correspondence with these assumptions. In other words, the expected forecast errors would be zero if the expected yield was calculated as the yield given by the ET. The reason for this is that today's yield would be adjusted by the market until it corresponded with the future expected yield.

But what if expected forecast errors are not zero under these conditions? If this should be the case we must conclude that at least one of those four assumptions is false. In this case, the assumptions of validity of RE and ET cannot be combined with EMH and constant risk premia, if there are non-zero expected prediction errors. They are in other words mutually exclusive, and we must choose not to believe one and assume that the others are valid. In accordance with Fama (1984), I choose to favour the fairly reasonable assumption of efficient markets and rational expectations. I also choose to trust the fairly straightforward expectations theory. However, like Fama, I'm not altogether convinced that the risk premia of the expectations theory are always constant, as is stated in the expectations theory. In order for us to test this, we need to make some additional assumptions or, at least, clarifying definitions of earlier assumptions. We also need to define what we want to call the "information set". Why do we need to do this? Here's why:

First of all, the concept of constant risk premia over time is part of the expectations theory. Thus, in this context, testing this assumption indeed implies testing the validity of the expectations theory as a whole. However, for practical reasons, we shall use this terminology and treat the two concepts as separate in all practical respects.

If we first make the additional assumption, indeed a sub-assumption of rational expectations, that future forecast errors are randomly distributed, then this has implications of interpretation of the market's risk premia. For example, if we can predict future forecast errors from our information set today, then risk premia cannot possibly be constant, given we've taken the other assumptions as true. Putting this in a clearer context, if for example the ET gives a certain expectation of the future one-year yield in one year's time, based on the risk premium between a two-year bond and one-year bill, then there should be no way of forecasting non-zero prediction errors if risk premia are indeed constant. In other words, if prediction errors of ET are assumed to be randomly distributed and non-zero prediction errors still can be forecasted from the information set, we conclude that the risk premium component of the ET expectation cannot be constant over time. It must have some covariance with some factor that we need to define. Factors of this sort make out what we call the *information set*. Thus we need to more clearly define the components of the information set.

6.2 The information set

This part of the analysis is, of course, subject to the arbitrary thoughts of the analyst, and it is therefore vulnerable to criticism. Hence it requires some motivation. The components that I intend to include are all macroeconomic variables, and should thus have some interest for investors and their expectations. The risk premium is constructed by the willingness of an investor to choose a long bond rather than another, shorter one. In other words, they're factors that affect the risk aversion of investors. The factors I'm including are:

1. **Inflation:** It cannot be ruled out that the level of inflation affects the risk adversity of investors, or rather their willingness to invest in long bonds. If inflation is high, then this causes the market increasingly to expect central bank actions against this, and so on. This, in turn, changes the expectations of future yields, as well as the risk aversion of investors.
2. **Exchange rate regime:** On November 19th 1992, due to international speculation, Sweden abandoned its fixed exchange rate regime and adopted a policy of "floating"

exchange rates. In the process, a policy of inflation prevention was also adopted. In other words, the central bank now uses its lending rate to keep inflation on a reasonable level[36]. This, in turn, affects how interest rates move and thus the way the market makes expectations, conceivably also affecting maturity preferences. Of course, this is a dummy variable in the regression analysis for the time periods before and after the change of the exchange rate regime.

3. **Yield spreads:** For any forecast at least two, often three, interest rates are involved as can be seen in section 3.5.2. Is risk attitude affected by the shape of the yield curve? For instance, is a sharply up-sloping yield curve synonymous with a certain degree of risk aversion? If so, this means that the slope of the yield curve affects the risk premia. However, in order to avoid multicolinearity, we use *yield spreads*. That is, for the above example we would use the difference in yield between one-year and two-year securities as variables in the regression analysis, rather than using each of the yields separately, since, in particular when using more than two rates, there is a multicolinearity problem. It could be pointed out that a standardized type of measurement, such as the three-month bill versus the five-year bond, could be used in all regressions. This is a valid point, since shorter combinations might not capture all aspects of the slope of the yield curve. However, it does provide other advantages. One such advantage is that the yield spread between the two (or three) bonds captures the risk premium between the two (or three) bonds in question better than the somewhat "blunt instrument" of a standardized measure. The use of *both* measures, I fear, would only lead to a compromise, providing less information than if only one measure was to be chosen.
4. **Time trend:** Finally, if none of the above components can explain why actual yields deviate from those predicted those predicted by the constant-premia ET, then perhaps there is a time trend in prediction errors. However, the existence of a time trend, other than the one represented by the exchange rate policy dummy, is difficult to theoretically explain and motivate. The only explanation that does not compromise the assumptions is the gradual shift of the market's risk aversion. This factor may however be good to capture other macroeconomic trends than the ones presented above.

36 Södersten et al, Marknad och politik, p. 152

6.3 Assumptions

In any case, the significance of any of the above variables in a regression analysis of this implies that prediction errors are forecastable to some degree, and thus, the ET with constant risk premia cannot be an appropriate model. Because of my assumptions of rational expectations and random disturbances, I've set the risk premia between two securities equal to the average over-time yield spread between them. In order to analyse whether forecastability of prediction errors is just the result of misspecified - *yet constant* - risk premia (rather than the result of non-constant premia), I'm using benchmark prediction using twice or none of the original premia. The latter is thus equal to the pure expectations hypothesis.

There is perhaps a feeling among readers that the distinction between some assumptions is vague. For example, one could argue that the failure of ET to predict future yields could just as well be the result of non-rational expectation as that of non-constant risk premia. This view, however is not constructive statement for at least two reasons:

- As shown above, the variations in risk aversion are easier to explain through the information set than would be any deviations from rational expectations.
- The concept of rational expectations is perhaps more plausible than the one of constant risk premia, at least when following the analogy of Fama (1984).

Following the reasoning above, the assumptions of the study are:

1. **Semi-strong market efficiency:** All publicly available relevant information is incorporated into the prices of bonds and bills. Prices, of course, are dependent on the expectation of future prices and yields. This form of efficiency has received the most support in studies[37]. It means that investors do not know the future actions of the central bank, but form expectations based on the available information
2. **Expectations theory:** The expectations theory is generally taken to be a valid description of the way that the market forms expectations of future yields. However, we make no assumptions regarding the properties of the risk premia within this framework.

37 Fama, 1991, p. 1575.

3. **Rational expectations:** The expectations hypothesis corresponds to the way the markets forms its expectations and prices. The expectations hypothesis is thus a valid economic theory for rational expectations of future yields. For this assumption we also make the following statements:
    a. It follows from our assumption of efficient markets that prediction errors are caused by new information in the marketplace after the forecasting date, affecting expectations and therefore the prices.
    b. These errors are randomly distributed, IID. This assumption is reasonable, since otherwise errors would be forecastable, and under efficient markets this would not be possible.

6.4 Actual implementation

6.4.1 Calculating zero rates

Before any analysis can take place, the data must be converted to zero rates. Conversion is performed using the process described in section 3.2. For the treasury bills, this is not necessary because they have no coupons and are thus reported in zero rates. For bonds, however, conversion must be performed since they are not reported in effective yield but rather in terms of coupon cash flows. The one-year zero is required to calculate the two-year zero, one- *and* two-year zeros are required to calculate the three-year zero, and so on. For this reason, we can never have *more* observations of two-year zeros than of one-year zeros, and so on. Hence, the higher the zero rate used, the fewer degrees of freedom we get, later in our analysis.

Conversion to effective yield does not alter risk properties. The coupons do decrease the interest rate risk of a bond, but this could just as easily be replicated using shorter bonds. Hence the zero rates provide the same properties of risk preference as the coupon rates, and may thus be used to interpret the risk behaviour of investors. Of course, this includes ascertaining the properties of the risk premium, the focus of the next section.

6.4.2 Calculating risk premia

The risk premium of a long bond over a short bond is obviously not observable to analysts. Indeed, it is merely a theoretical application of a market phenomenon. Investors do not speak in terms of what premium they would demand to be indifferent between a long and a short bond before they choose their investment. They simply choose the one they prefer and market prices adjust accordingly. Even now, analysts can still not measure risk premia, since the securities have different maturities. Measuring the risk premium thus requires knowledge of expectations of future yields, which are - of course - also unobservable. Thus, some assumptions regarding the nature of expectations are necessary in order to measure, or rather to *estimate*, risk premia.

I've already acknowledged my assumption of rational expectations, random disturbances and efficient markets. Since the market has RE, and expected prediction errors are zero, then an efficient market would expect the risk premium to be simply the difference between a short and a long bond. And thus a constant risk premium would equal the average difference in yield over time between a long and a short bond. Consequently, we need to calculate all differences between long and short bonds and calculate the means of every such series. Of course, some series will most likely *not* be mean-reverting and we may not be able to conclude that they indeed *do* have a constant mean. Therefore, we must perform a Dickey-Fuller test of stationarity to see if the series can be used in our analysis. If the series clearly does not have a constant mean – such as when there is a moving average – we can forget about implementing it as a constant premium. It simply would not make sense.

Furthermore, our theoretical assumptions tell us that a long bond should usually give more yield than a short bond. In other words, the average difference between the bonds should be positive. This is tested using a student's *t*-test, and series not displaying positive significance are rejected from further analysis.

Once adequate testing has been completed, we need to find matches between the premia that are valid for analysis in order to see which future yields we can estimate. This is discussed more thoroughly in section 7.1.3.

6.4.3 Modeling expected future interest rates

We have calculated risk premia as the difference in yield, from zero rate data on a yearly basis. Hence, the risk premia are also on a yearly basis. Thus, we define the risk premia between a *y*-period bond (or bill) and an *x*-period bond (or bill) as Φ_{yx}. From this definition, and the definitions in the sections 3.4 and 3.1, we can define the models for calculating the future treasury yields and bond yields, respectively, as:

(Equation 24)

Treasury bills:

$$\left(1+\frac{n}{12}y_{nt}\right)=\left[1+\frac{m}{12}y_{mt}\right]E_t\left[1+\left(\frac{n-m}{12}\right)y_{n-m,t+m}+\frac{n-m}{12}\Phi_{n,n-m}\right]$$

$$\Rightarrow E_t\left[y_{n-m,t+m}\right]=\frac{\left(\dfrac{n}{n-m}\right)y_{nt}-\left(\dfrac{m}{n-m}\right)y_{mt}}{1+\dfrac{m}{12}y_{mt}}-\Phi_{n,n-m}$$

Government bonds:

(Equation 25)

$$\left(1+y_{nt}\right)^n=\left(1+y_{mt}\right)^m E_t\left(1+y_{n-m,t+m}+\Phi_{n,n-m}\right)^{n-m}$$

$$\Rightarrow E_t\left(y_{n-m,t+m}\right)=\left[\frac{\left(1+y_{nt}\right)^n}{\left(1+y_{mt}\right)^m}\right]^{\frac{1}{n-m}}-\left(1+\Phi_{n,n-m}\right)$$

For reason of validity, we also perform these calculations using a zero premium and a double premium as benchmarks. The zero premium of course completely corresponds to the pure expectations theory.

6.4.4 Interpreting the risk premium

In order to see what impact the risk premium has for the expected future yield, we need to calculate the first-order partial derivatives of the expectations theory relations expressed in equations 24 and 25.

Treasury bills

$$\frac{\partial E_t\left\lfloor y_{n-m,t+m}\right\rfloor}{\partial \Phi_{n,n-m}} = -1 < 0 \qquad \text{(Equation 26)}$$

In other words, the premium has a negative correlation with the expected future yield. The higher the premium, the lower the expected yield. Of course, the effect of higher risk premia on prediction errors, addressed in the next section, is the same as the effect on expected yield, as can be shown from equation 28.

Government bonds

$$\frac{\partial E_t\left(y_{n-m,t+m}\right)}{\partial \Phi_{n,n-m}} = -1 < 0 \qquad \text{(Equation 27)}$$

Not surprisingly, the effect for government bonds is the same as for treasury bills - There is a negative correlation between premium and expected yield. These relationships will be important when interpreting the regression analysis later.

6.4.5 Calculating prediction errors

Last, but not least, before the analysis can start we need to calculate the prediction errors of the ET constant-premia predictions. This is just a simple matter of subtracting the actual yield from the one predicted by our ET calculations as presented in the section above. Defining prediction errors as ξ, this is done using the principle

$$\xi = E_t\left(y_{n-m,t+m}\right) - y_{n-m,t+m}\,. \qquad \text{(Equation 28)}$$

In other words, if the predicted yield is higher than the actual yield, we have a positive prediction error. When this is done for all combinations of maturities and for all three premia, student's *t*-tests are performed to see if any prediction is on average "right", that is, if any prediction error have a mean of zero.

6.4.6 Regression analysis

For the next step, the prediction errors are used a dependent variable in a regression analysis. This means that for all non-zero prediction error series, we make a regression using the information set in section 6.2 as independent variables. If there is a significant correlation between the dependent and the independent variables, we may have non-constant premia.

7 Results

In this chapter, the results of the analysis are presented and commented.

7.1 Calculations of risk premia

7.1.1 Student's t-test for positive significance

Treasury bills

In table 7.1 below, the results of tests of significance are displayed. For any pair of t-bill maturities, the difference between them has been calculated using the method discussed in section 6.4.2. They were then tested for the hypothesis

$$H0: \mu > 0$$
$$H1: \mu \leq 0$$

The significant series are denoted by a sign of relative significance. The sign "*"indicate at least 10 % significance, "**" is 5 % and "***" is 1 %. We need at least 5 % significance to use a series in this case.

Table 7.1 – t-test of positive mean

Medel	*1M*	*2M*	*3M*	*4M*	*5M*	*6M*	*7M*	*8M*	*9M*	*10M*	*11M*
2M	-0,061										
3M	-0,063	-0,002									
4M	-0,053	0,012	0,022 (***)								
5M	-0,036	0,028 (***)	0,039 (***)	0,016 (***)							
6M	-0,006	0,056 (***)	0,057 (***)	0,027 (***)	0,011 (***)						
7M	-0,004	0,060 (***)	0,071 (***)	0,049 (***)	0,032 (***)	0,022 (***)					
8M	0,015	0,079 (***)	0,090 (***)	0,068 (***)	0,051 (***)	0,040 (***)	0,019 (***)				
9M	0,032	0,095 (***)	0,109 (***)	0,087 (***)	0,071 (***)	0,061 (***)	0,040 (***)	0,022 (***)			
10M	0,130 (***)	0,180 (***)	0,193 (***)	0,163 (***)	0,143 (***)	0,130 (***)	0,091 (***)	0,069 (***)	0,045 (***)		
11M	0,147 (***)	0,197 (***)	0,210 (***)	0,181 (***)	0,161 (***)	0,148 (***)	0,108 (***)	0,087 (***)	0,062 (***)	0,018 (***)	
12M	0,116 (***)	0,198 (***)	0,206 (***)	0,176 (***)	0,160 (***)	0,154 (***)	0,128 (***)	0,109 (***)	0,084 (***)	0,031 (***)	0,014 (***)

As we can see, most of the combinations are significant, except for some of the lower ones of one-month and two-month bills.

Government bonds

The same principle as for the treasury bills is used for government bonds. The results are presented in the table below.

Table 7.2 – t-test of positive mean

Medel	*1Y*	*2Y*	*3Y*	*4Y*	*5Y*	*6Y*	*7Y*	*8Y*	*9Y*
2Y	0,545 (***)								
3Y	0,976 (***)	0,431 (***)							
4Y	1,487 (***)	0,955 (***)	0,529 (***)						
5Y	2,114 (***)	1,485 (***)	1,054 (***)	0,515 (***)					
6Y	2,577 (***)	2,045 (***)	1,618 (***)	1,089 (***)	0,574 (***)				
7Y	3,192 (***)	2,646 (***)	2,215 (***)	1,660 (***)	1,161 (***)	0,570 (***)			
8Y	3,821 (***)	3,289 (***)	2,863 (***)	2,334 (***)	1,819 (***)	1,245 (***)	0,674 (***)		
9Y	4,442 (***)	3,917 (***)	3,495 (***)	2,970 (***)	2,458 (***)	1,887 (***)	1,321 (***)	0,651 (***)	
10Y	5,229 (***)	4,682 (***)	4,251 (***)	3,669 (***)	3,198 (***)	2,579 (***)	2,037 (***)	1,335 (***)	0,821 (***)

In this case, all of the combinations are indeed significant, and the premium seems to increase with difference in maturity. This gives support to the liquidity preference theory.

7.1.2 DF-test for stationarity of risk premia

Treasury bills

We also perform tests of moving average using a Dickey-Fuller test with a constant. The results of this test are displayed in the table below. As before, we reject the series that do not have a constant mean.

Table 7.3 – Dickey-Fuller test of moving average, treasury bills

ADF	*1M*	*2M*	*3M*	*4M*	*5M*	*6M*	*7M*	*8M*	*9M*	*10M*	*11M*
2M	-30,24 (***)										
3M	-26,64 (***)	-21,67 (***)									
4M	-25,93 (***)	-20,32 (***)	-18,34 (***)								
5M	-24,68 (***)	-16,95 (***)	-12,91 (***)	-14,90 (***)							
6M	-24,23 (***)	-17,03 (***)	-11,38 (***)	-11,13 (***)	-19,30 (***)						
7M	-23,21 (***)	-16,19 (***)	-10,98 (***)	-10,86 (***)	-15,62 (***)	-11,33 (***)					
8M	-22,76 (***)	-15,29 (***)	-9,40 (***)	-8,96 (***)	-12,10 (***)	-11,37 (***)	-16,03 (***)				
9M	-21,02 (***)	-13,92 (***)	-11,86 (***)	-13,10 (***)	-16,87 (***)	-19,57 (***)	-24,36 (***)	-30,21 (***)			
10M	-19,80 (***)	-12,74 (***)	-7,41 (***)	-7,51 (***)	-10,22 (***)	-8,98 (***)	-9,68 (***)	-11,48 (***)	-28,39 (***)		
11M	-19,79 (***)	-12,12 (***)	-8,76 (***)	-8,63 (***)	-9,48 (***)	-9,40 (***)	-10,32 (***)	-13,64 (***)	-24,56 (***)	-19,14 (***)	
12M	-20,69 (***)	-13,83 (***)	-9,73 (***)	-9,37 (***)	-11,42 (***)	-10,82 (***)	-10,71 (***)	-12,39 (***)	-22,70 (***)	-14,02 (***)	-18,59 (***)

Clearly, all premia from combinations of treasury bills are stationary. This means that all series that are positively significant in table 7.1 can be used in further analysis.

Government bonds

Again, government bond premia follow the same principle as treasury bills.

Table 7.4 – Dickey-Fuller test of moving average, government bonds

ADF	*1Y*	*2Y*	*3Y*	*4Y*	*5Y*	*6Y*	*7Y*	*8Y*	*9Y*
2Y	-11,090 (***)								
3Y	-7,687 (***)	-4,524 (***)							
4Y	-5,922 (***)	-3,757 (***)	-5,494 (***)						
5Y	-5,268 (***)	-2,657 (*)	-2,942 (**)	-5,374 (***)					
6Y	-4,491 (***)	-2,456	-2,441	-3,412 (**)	-3,763 (***)				
7Y	-3,725 (***)	-2,186	-2,137	-2,558	-2,249	-3,614 (***)			
8Y	-3,368 (***)	-2,083	-1,931	-2,189	-2,032	-2,523 (**)	-3,633 (***)		
9Y	-2,985 (**)	-1,988	-1,782	-1,896	-1,661	-1,980	-2,189 (**)	-3,875 (***)	
10Y	-2,563 (*)	-1,747	-1,640	-1,730	-1,488	-1,689	-1,576	-2,063	-2,655 (**)

The premia of bonds are more varying over time than those of treasury bills. Especially for "short" combinations, such as two-year bonds and three-year bonds, the premium is *not* a random walk. However, for longer combinations, the constant is less reliable. We conclude that all combinations that are significant on the 5 % level can be included in the analysis, since they are all positively significant in table 7.2. These combinations are all valid premia for further analysis.

7.1.3 Pairing of valid risk premia

In order to find out which future yields we can estimate, we need to examine which yield spreads are significantly positive. We can then, for all for all risk premia $\Phi_{n,n-m}$, make ET predictions that satisfy the condition $(n-m)+m=n$. In other words, we need to define all valid[38] risk premia that satisfy this relation[39]. When this is performed, we see that the valid pairs of bills and bonds are:

Table 7.5 – Valid pairs of treasury bill premia, and yields that can be predicted from these

	1M	2M	3M	4M	5M	6M	7M	8M	9M	10M	11M
2M	NA										
3M	NA	NA									
4M	NA	NA	$E_t[y_{1,t+3}]$								
5M	NA	$E_t[y_{3,t+2}]$	$E_t[y_{2,t+3}]$	$E_t[y_{1,t+4}]$							
6M	NA	$E_t[y_{4,t+2}]$	$E_t[y_{3,t+3}]$	$E_t[y_{2,t+4}]$	$E_t[y_{1,t+5}]$						
7M	NA	$E_t[y_{5,t+2}]$	$E_t[y_{4,t+3}]$	$E_t[y_{3,t+4}]$	$E_t[y_{2,t+5}]$	$E_t[y_{1,t+6}]$					
8M	NA	$E_t[y_{6,t+2}]$	$E_t[y_{5,t+3}]$	$E_t[y_{4,t+4}]$	$E_t[y_{3,t+5}]$	$E_t[y_{2,t+6}]$	$E_t[y_{1,t+7}]$				
9M	NA	$E_t[y_{7,t+2}]$	$E_t[y_{6,t+3}]$	$E_t[y_{5,t+4}]$	$E_t[y_{4,t+5}]$	$E_t[y_{3,t+6}]$	$E_t[y_{2,t+7}]$	$E_t[y_{1,t+8}]$			
10M	$E_t[y_{9,t+1}]$	$E_t[y_{8,t+2}]$	$E_t[y_{7,t+3}]$	$E_t[y_{6,t+4}]$	$E_t[y_{5,t+5}]$	$E_t[y_{4,t+6}]$	$E_t[y_{3,t+7}]$	$E_t[y_{2,t+8}]$	$E_t[y_{1,t+9}]$		
11M	$E_t[y_{10,t+1}]$	$E_t[y_{9,t+2}]$	$E_t[y_{8,t+3}]$	$E_t[y_{7,t+4}]$	$E_t[y_{6,t+5}]$	$E_t[y_{5,t+6}]$	$E_t[y_{4,t+7}]$	$E_t[y_{3,t+8}]$	$E_t[y_{2,t+9}]$	$E_t[y_{1,t+10}]$	
12M	$E_t[y_{11,t+1}]$	$E_t[y_{x,10+2}]$	$E_t[y_{9,t+3}]$	$E_t[y_{8,t+4}]$	$E_t[y_{7,t+5}]$	$E_t[y_{6,t+6}]$	$E_t[y_{5,t+7}]$	$E_t[y_{4,t+8}]$	$E_t[y_{3,t+9}]$	$E_t[y_{2,t+10}]$	$E_t[y_{1,t+11}]$

38 That is, risk premia that are stationary and significantly positive.

39 See section 3.5.2 to see how this is done

Table 7.6 – Valid pairs of government bond premia, and yields that can be predicted from these

	1Y	2Y	3Y	4Y	5Y	6Y	7Y	8Y	9Y
2Y	$E_t[y_{1,t+1}]$								
3Y	$E_t[y_{2,t+1}]$	$E_t[y_{1,t+2}]$							
4Y	$E_t[y_{3,t+1}]$	$E_t[y_{2,t+2}]$	$E_t[y_{1,t+3}]$						
5Y	$E_t[y_{4,t+1}]$	NA	$E_t[y_{2,t+3}]$	$E_t[y_{1,t+4}]$					
6Y	$E_t[y_{5,t+1}]$	NA	NA	$E_t[y_{2,t+4}]$	$E_t[y_{1,t+5}]$				
7Y	$E_t[y_{6,t+1}]$	NA	NA	NA	NA	$E_t[y_{1,t+6}]$			
8Y	$E_t[y_{7,t+1}]$	NA	NA	NA	NA	NA	$E_t[y_{1,t+7}]$		
9Y	$E_t[y_{8,t+1}]$	NA	NA	NA	NA	NA	$E_t[y_{2,t+7}]$	$E_t[y_{1,t+8}]$	
10Y	NA	NA	NA	NA	NA	NA	NA	NA	$E_t[y_{1,t+9}]$

We now have 76 different sets of estimations of future yields, 20 bond yields and 56 treasury yields. The next step is to calculate the estimated future yields and their respective prediction errors.

7.2 Calculation of expectations theory prediction errors

7.2.1 Student's t-test for $\xi = 0$

Treasury bills

We performed *t*-tests for all prediction errors. The results of these tests are found in table A.1 in the appendix. The test is a double-sided test of the null hypothesis $\xi = 0$. The results are intriguing. Regardless of premium multiplier (0, 1 or 2), the predictions are nearly always higher than the actual yields, in terms of mean value. This is reflected in the *t*-statistics. Indeed all prediction errors are significantly nonzero. The fact that all predictions seem to be above zero leads us to believe that premia are on average to low, even in the case of the double premium. However, one should be careful about making such hasty conclusions, especially since these results are based on a constant risk premium.

Government bonds

The results for government bonds are found in the appendix, in table A2. All double premium prediction errors are significantly negative on the 1% significance level, while standard premium predictions are mixed, although “positive is in majority”. Prediction errors from the PET are all positively nonzero. This implies that a premium with a multiplier somewhere between one and zero would conceivably produce prediction errors that were *not* significantly nonzero. That is, predictions that on average would be “right”. Of course, this is of little practical interest, since we do not believe risk premia to be constant. But it is an interesting thought nevertheless. Of course, again we should be careful about interpreting these results.

7.2.2 ADF-test for stationarity of prediction errors

To conclude that prediction errors aren’t in conflict with our assumptions, tests for stationarity were conducted using the ADF method. The results are displayed below, in table 7.7 and 7.8.

Table 7.7. – Stationarity of treasury bill predictions

	Prediction error	***ADF statistic***			***Prediction error***	***ADF statistic***	
1	u[E(r9,t+1)]	-16.18504	(***)	**29**	u[E(r1,t+5)]	-8.620927	(***)
2	u[E(r10,t+1)]	-15.34401	(***)	**30**	u[E(r2,t+5)]	-10.27791	(***)
3	u[E(r11,t+1)]	-15.30137	(***)	**31**	u[E(r3,t+5)]	-8.699721	(***)
4	u[E(r3,t+2)]	-12.73336	(***)	**32**	u[E(r4,t+5)]	-9.993753	(***)
5	u[E(r4,t+2)]	-12.43555	(***)	**33**	u[E(r5,t+5)]	-5.695166	(***)
6	u[E(r5,t+2)]	-12.24410	(***)	**34**	u[E(r6,t+5)]	-5.693894	(***)
7	u[E(r6,t+2)]	-12.12308	(***)	**35**	u[E(r7,t+5)]	-7.158261	(***)
8	u[E(r7,t+2)]	-12.62489	(***)	**36**	u[E(r1,t+6)]	-10.17334	(***)
9	u[E(r8,t+2)]	-11.23414	(***)	**37**	u[E(r2,t+6)]	-8.660132	(***)
10	u[E(r9,t+2)]	-10.38348	(***)	**38**	u[E(r3,t+6)]	-10.43641	(***)
11	u[E(r10,t+2)]	-11.03176	(***)	**39**	u[E(r4,t+6)]	-8.398172	(***)
12	u[E(r1,t+3)]	-12.23420	(***)	**40**	u[E(r5,t+6)]	-6.607491	(***)
13	u[E(r2,t+3)]	-10.80965	(***)	**41**	u[E(r6,t+6)]	-7.778956	(***)
14	u[E(r3,t+3)]	-11.26052	(***)	**42**	u[E(r1,t+7)]	-13.91467	(***)
15	u[E(r4,t+3)]	-11.10062	(***)	**43**	u[E(r2,t+7)]	-11.13314	(***)
16	u[E(r5,t+3)]	-11.01774	(***)	**44**	u[E(r3,t+7)]	-8.237478	(***)
17	u[E(r6,t+3)]	-11.28881	(***)	**45**	u[E(r4,t+7)]	-6.324042	(***)
18	u[E(r7,t+3)]	-11.05926	(***)	**46**	u[E(r5,t+7)]	-7.136076	(***)
19	u[E(r8,t+3)]	-10.03336	(***)	**47**	u[E(r1,t+8)]	-12.53063	(***)
20	u[E(r9,t+3)]	-11.84631	(***)	**48**	u[E(r2,t+8)]	-8.015544	(***)
21	u[E(r1,t+4)]	-15.15489	(***)	**49**	u[E(r3,t+8)]	-5.834150	(***)
22	u[E(r2,t+4)]	-9.614906	(***)	**50**	u[E(r4,t+8)]	-6.903525	(***)
23	u[E(r3,t+4)]	-9.860368	(***)	**51**	u[E(r1,t+9)]	-10.81035	(***)
24	u[E(r4,t+4)]	-9.909138	(***)	**52**	u[E(r2,t+9)]	-6.994610	(***)
25	u[E(r5,t+4)]	-10.34153	(***)	**53**	u[E(r3,t+9)]	-4.652844	(***)
26	u[E(r6,t+4)]	-8.963289	(***)	**54**	u[E(r1,t+10)]	-8.529376	(***)
27	u[E(r7,t+4)]	-7.682921	(***)	**55**	u[E(r2,t+10)]	-6.453778	(***)
28	u[E(r8,t+4)]	-9.156475	(***)	**56**	u[E(r1,t+11)]	-8.947320	(***)

Clearly, we find no evidence of unit roots in any prediction. The prediction errors are all mean-reverting. For us, this implies that disturbances are fairly quickly absorbed and do not linger to cause any spurious regression problems. This means that we can expect fairly valid results from the regression analysis.

Table 7.8. – Stationarity of government bond predictions

	Prediction error	ADF statistic			Prediction error	ADF statistic	
1	uE(1Y+1)	-3.851016	***	11	uE(1Y+3)	-2.694347	*
2	uE(2Y+1)	-2.794880	*	12	uE(2Y+3)	-1.831481	
3	uE(3Y+1)	-2.378506		13	uE(1Y+4)	-2.318785	
4	uE(4Y+1)	-2.292079		14	uE(2Y+4)	-1.771591	
5	uE(5Y+1)	-2.049482		15	uE(1Y+5)	-2.597293	*
6	uE(6Y+1)	-1.956710		16	uE(1Y+6)	-1.797291	
7	uE(7Y+1)	-1.843063		17	uE(1Y+7)	-2.756763	*
8	uE(8Y+1)	-1.773694		18	uE(2Y+7)	-1.796398	
9	uE(1Y+2)	-3.334447	**	19	uE(1Y+8)	-2.936399	**
10	uE(2Y+2)	-2.228016		20	uE(1Y+9)	-2.096649	

Clearly, the longer prediction periods have taken their toll on the government bond predictions – Only for three series can we reject the null hypothesis of a unit root. Regressions performed on this series would not be credible. We must differentiate the series in order to avoid spurious regressions.

7.3 Regression analysis

The results of the regression analysis are rather extensive, and are therefore found in the appendix, tables A.3 and A.4. The regression analysis means to investigate the OLS relationship defined as

$$\xi_{n-m,t+m} = \beta_1 x_t + \beta_2 \pi_t + \beta_3 t + \beta_4 \left(y_{nt} - y_{n-m,t} \right) + \varepsilon_t \qquad \text{(Equation 29)}$$

where:

- ξ_{n-mt+m} is the prediction error of an *(n-m)*-period expected yield at time *t+m*.
- x_t is a dummy variable, equal to 0 for a fixed exchange rate policy and equal to 1 for a floating exchange rate policy.

- y_{it} is the yield on a *i*-period bond at time *t*. $y_{it} - y_{jt}$ is the yield spread between an *i*-period and a *j*-period bond at time *t*.
- π_t is the inflation rate at time *t*.

No intercept is included, since this would be difficult to interpret, and it would result in the other parameters being equal for all three premia, since all that differ between the three prediction errors are a constant. We will perform significance tests of the parameters with the null hypothesis

$$H0 : \beta_i = 0$$

Parameters with a significance level inferior to 5 % are rejected. In order to avoid flawed regressions, observations containing outliers were omitted from the regression analysis. More specifically, this affected the unusually high rates around November 1992, and zero rates and prediction errors calculated from these high rates. These observations were therefore not included.

7.3.1 Regression analysis of treasury bills

First of all, inflation undoubtedly seems to have an impact on prediction errors for treasury bills. There is not a single instance of the inflation parameter showing less than 1 % significance level. In every single case, the sign of the inflation parameter is positive. This means that a high inflation pushes expectations up, implying the presence of a lower risk premium[40], *ceteris paribus*. This corresponds to our line of reasoning that a high inflation implies a lower risk aversion and therefore a higher risk premium. It may be seen as strange that the risk premium would decrease when the inflation is high, since this type of circumstances is associated with uncertainty. But one must remember that the risk premium is a measure of how much expected excess return the market demands to prefer a long bill to a short one. In other words, it measures how much more attractive short bills are to long bills. In times of high inflation there is great uncertainty, especially about short rates, and it's understandable that markets may prefer longer bills more, since these are less volatile than

40 See sections 6.4.4 and 6.4.5 for the relationship between prediction errors and risk premia.

shorter bills. Of course, this may be truer for bonds than for t-bills, but nevertheless the pattern is clear. Inflation makes the market prefer longer t-bills to a higher degree.

Also, the dummy seems to affect risk premia, since there are high significance levels. However, for regressions 51 through 56, the parameter is not significant or six instances out of fifty-six. In other words, exchange rate policy seems to be an important factor for the experienced risk of investors.

In all cases where the dummy parameter is significant, it has a positive sign. Since the dummy variable equals one for a “floating” exchange rate policy and zero for a fixed ditto, this implies that a “floating” policy is associated with a lower risk aversion and risk premia for investors, *ceteris paribus*. Again, this corresponds to our line of reasoning that a floating exchange rate policy means a lower risk aversion. Yet again, it’s reasonable to believe that a floating exchange rate policy makes short rates harder to predict, in turn making longer bills more attractive, as in the case of inflation.

Furthermore, the yield curve parameters do not display the same behaviour. Regressions 2, 6 through 8, 10, 11, 17 through 20, 26, 27, 33 through 35 and 46 are not significant. This corresponds to sixteen regressions out of fifty-six. In other words, there is evidence of the shape of the yield curve affecting risk premia, but not to the extent that inflation and exchange rate policy does. Regardless of whether there is an effect on premia or not, almost all of the significant parameters are negative. This would imply that a high yield spread (a sharp slope of the yield curve) is synonymous with a high risk premium, since a high slope drives predictions downwards, *ceteris paribus*. In terms of risk, a low slope of the yield curve means short bills are relatively more attractive to investors. This is, of course, even taking into account the relatively high attractiveness of short bills that is evident from the high slope. If there are indeed non-constant risk premia, it can therefore be said that some of the effect is in the slope, and some is in the higher premium. Or perhaps rather that, had there been *constant* risk premia, the slope would be lower. According to our findings, this scenario is of course unrealistic – premia are not constant. But where does this effect come from, and why is it not simply taken into account by the slope? Well, first of all, the slope doesn’t only take into account the premia, but also *expectations*. Thus, the change in the premium must be due to some specific type of expectations associated with a particular slope of the yield curve.

Perhaps an explanation could be that a very high slope of the yield curve is associated with uncertainty about future long rates compared to short rates, which makes the long bills relatively less attractive. Also, it's interesting to note that the insignificant parameters all come from the last six regressions. These are the ones that have yield spreads that are very close to each other in maturity, and therefore do not vary as much over time compared to yield spreads of more different maturities. This could be part of the explanation of why these parameters are not significant.

Looking at the time trend parameter, regressions 4, 6, 7, 9 through 11, 26, 33, 34, 39 through 41, 44 through 50 are all non-significant for at least one parameter. This makes 19 regressions out of fifty-six, and it also displays the most diverse results across different parameters of any factor in the regression analysis. This implies that caution should be used when interpreting the results. The overwhelming majority of the significant parameters have a negative sign.

Thus, there is some evidence of a time trend, apart from the time factor capture by the shift in the exchange rate policy (the dummy is of course also a time trend variable in a way). The later the observation, the lower the prediction error, and this implies an increasing risk premium over time. In other words, investors have become biased over time towards the shorter yields for some reason. Conceivably, a plausible explanation of this could be that the risk aversion of investors - expressed as the propensity to invest in short bonds compared to long bonds - has changed over the course of the last 22 years as the financial markets have matured and become less regulated, providing better conditions for investors and so on. Or perhaps, macroeconomics and actual trends in the money market may also be accountable to this phenomenon. Perhaps long bonds have become relatively harder to predict, which would cause the market to avoid these securities tom a larger extent. In any event, the result would be that investors gradually develop a bias towards shorter bonds. However, these are merely guesses, and I'll let questions like these be answered by future researchers.

Moreover, the benchmark regressions provide little or no comparison, since they are very similar to the standard regressions. Most of the significance levels and the signs are virtually the same, and the signs are virtually the same. This helps us be fairly certain that it is indeed not the *magnitude* of the risk premia that is causing prediction errors, but rather the fact that it is restricted to be *constant*.

7.3.2 Regression analysis of government bonds

In the case of government bonds, it should be noted that the dependent variable has been differentiated. That is, it is now the one-period *change* in prediction error from the previous period that is used as the dependent variable. This can be expressed as

$$\Delta\xi_t = \xi_t - \xi_{t-1} \qquad \text{(Equation 30)}$$

The yield spread variable, and the inflation variable were also transformed in the same way. However, the dummy variable and the time trend variable were not, for obvious reasons.

For government bonds, this is where the concept of risk aversion really becomes crucial, due to the very long maturities of some of the bonds. In the case of government bonds, we find that the inflation variable does not at all have the same impact as for treasury bills. Only five out of twenty regressions, regressions 2, 13 and 18 through 20 are significant for this parameter. In all of these cases, the sign is positive, implying that high inflation means lower risk premia. The relationship would thus be the same as for the treasury bills. Therefore, it's surprising that the relationship seems to be stronger for treasury bills, contrary to what I suspected in the previous section. Nevertheless, there is a weak relationship of inflation causing the market to prefer longer securities or, equivalently, a lower risk premium. Of course, this is highly unreliable because the poor overall significance levels give little support to any such notions.

Furthermore, the dummy variable parameter shows mixed behaviour. Only regressions 2 through 6 show significance in the parameter. For the significant cases, and indeed most of the non-significant ones, the parameter has a negative sign, contrary to the treasury bill regressions. This gives the uncertain implication of the opposite relationship. In other words, a floating exchange rate policy would mean that prediction errors are low, *ceteris paribus*, and that this is caused by high risk premia. Investors avoid long securities and choose shorter bonds. I cannot give an exact explanation of why the treasury bills and the government bonds do not follow the same pattern, but generally, I must assume that it has to do with the investor's view of the risk profile of different maturities being affected by the exchange rate policy. In any case, it should be stressed that we are, in a way, comparing apples and oranges. The risk premia for treasury bills are, for example the six-month yield over the two-month, whereas the bond premia are rather the six-*year* over the two-*year*. In other words, we are talking of completely different time spans, and completely different risks of the securities. It should be noted, also, that for many of the prediction errors, predictions are so far into the future that very few prediction errors actually coincide with the fixed exchange rate policy. This could cause lower significance levels for these regressions. For the same reason, there is a reduction in degrees of freedom, impairing inference.

The yield curve parameters show very high significance levels. In fact, for every single regression, both yield curve parameters display p-values lower than 1 %. The impact of the yield curve seems unquestionable. Contrary to the treasury bill parameters, all signs are positive. This means that a sharp slope of the yield curve is associated with lower risk premia. It should be noted that the yield spreads measured in this context cover more diverse maturities, and are therefore higher and more volatile than the yield spreads of treasury bills. The slope seems to be more connected to risk, and therefore to the risk premium. Again, it is difficult to give an exact explanation of why the treasury bills and the government bonds do not follow the same pattern. So yet again, one guess is that the investors risk aversion and/or expectations are for some reason affected by, or associated with, a particular shape of the yield curve. And of course, we can’t really compare.

Regarding the time trend parameters, regressions 2 and three 3 are significant, all other regressions are non-significant. The parameters have a positive sign, again contrary to the treasury regressions. This implies that perhaps there is an opposite relationship, but if so, it is vague. It should be noted that even the non-significant parameters all have positive signs, and there are quite a few p-values below 10 %. Nevertheless, the overall significance is too weak for any conclusions to be drawn.

The benchmark regressions, finally, give virtually the same results as the standard risk premium regressions. Since no premium and a double premium give the same results as the standard premium, we conclude again that it is not the *size* of the premium that determines prediction errors, so much as the *movements* of the premium. Thus, the benchmark regressions give support to our hypothesis of non-constant risk premia.

8 Conclusions and discussion

8.1 Summary

From my analysis, a few conclusions can be drawn. These are presented in the list and table below.

- For most combinations of treasury bills, and *all* combinations of government bonds, longer maturity equals higher yield. This corresponds to the liquidity preference theory.
- All combinations of yield differentials for treasury bills are stationary.
- About half of the combinations of government bonds are stationary, mostly the ones that are "close" in terms of maturity.
- All prediction errors for treasury bills are above zero.
- Bonds display mixed behaviour, with double premium prediction errors generally below zero, standard premiums both positive and negative, and PET prediction errors positive on average.
- All treasury bill prediction errors are stationary.
- Only a few bond prediction errors are stationary.
- There seems to be a negative relationship between inflation and the risk premium for treasury bills. The higher the inflation, the higher the risk premium we can expect.
- The same seems to be true for government bonds, but the results are inconclusive.
- The same applies to the exchange rate policy in the case of treasury bills. A floating exchange rate policy also implies a higher risk premium.
- The reverse relationship applies in the case of government bonds.
- There also seems to be a tendency for the risk premium to increase over time in the case of treasury bills.
- There are signs of the opposite relationship being present for government bonds, but the results are inconclusive.
- Furthermore, there are signs that a sharp slope of the yield curve is associated with high risk premium, because it tends to make predictions to high.
- The reverse relationship applies to government bonds.

Table 8.1. – Summary of overall results of regression analysis

	Treasury bills	**Government bonds**
Inflation	-	(-)
Exchange rate policy dummy	-	+
Time trend	+	(-)
Yield spread	+	-

8.2 Analysis

The fact that longer securities give higher yields than shorter securities hardly comes as a surprise. This is observable every day in money market quotations.

Yield differentials between treasury bills are all stationary. This is also true for combinations of bonds that do not differ too much in maturity. It seems that the difference in maturity is what's crucial to the stationarity of the yield differential. This could partly be explained by the fact that long maturities are more volatile than short maturities.

Prediction errors for treasury bills are on average above zero. This means that predicted yields are on average "too low" and that (following our line of reasoning from section 6.4.4) this means that the risk premia are on average "to high". But as mentioned before, this is not relevant when premia are not constant.

Prediction errors from government bonds are on average below zero, except from PET predictions, that are on average above zero. This implies that actual premia, had they been constant, would be somewhere between standard ET and PET. Of course, this notion makes no practical sense since different premia would have different impact at different time, and of course also because we conclude that risk premia are in fact *not* constant. Even so, it remains an interesting point. The fact that none of the predictions are correct on average (that is, all of the prediction errors are significantly nonzero) would only matter if risk premia were constant. But, indeed even if predictions were on average zero, this would not necessarily mean that predictions errors would not be predictable. They could still be non-constant.

The treasury bill prediction errors are all stationary. This is fairly reasonable because yield spreads are stationary for treasury bills. Certainly, the opposite applies for government bonds, although the yield spreads used for analysis were indeed stationary. One should be careful when interpreting this point, but it is safe to say that there does seem to be a connection. Yield spreads of government bonds are simply more volatile and unpredictable.

Focusing on the regression analysis now, it can be concluded that both for treasury bills and government bonds, there are too many significant parameters - most of them of the same sign (that is, for bills and bonds *respectively*) - for the information set for this to simply be discarded as a coincidence. Of course it does not tell us anything about how much of the prediction errors that are caused by disturbances and how much is caused by variation in the risk premia. But nevertheless, there is significant covariance, and thus prediction errors are forecastable to some degree.

Inflation seems to decrease the risk premia, especially for treasury bills. This is because inflation drives up prediction errors, which is a sign of predictions being too high, relatively speaking. This is the result of low risk premia. In other words, it seems that high inflation makes investors less risk averse, decreasing risk premia. An explanation could be that high inflation makes forecasting of future short rates harder, leading investors to choose longer-term securities.

Furthermore, a floating exchange rate policy implies lower risk premia for investors, compared to a fixed exchange rate policy, in the case of treasury bills. Again, this is because the former drives up prediction errors. This could perhaps be the results of short interest rates being more difficult to predict, when monetary policy is no longer directed towards following another currency. This, in turn, makes short bonds more uncertain relative to longer bonds, and therefore less desirable for investors. However, the opposite relationship applies for government bonds.

Thirdly, there is an indistinct tendency for the risk premium to increase over time. That is, the later the prediction, the lower the prediction error, *ceteris paribus*. This could possibly be attributable to long-term trends in the money market, whatever these may be. These, in any case, would cause the market to gradually prefer shorter bills to longer. However the fact that the time trend gets no support in the bonds analysis speaks against this notion. In conclusion, perhaps it is merely the result of falling inflation levels and similar time trends for other variables in the information set, and so on.

Large yield spreads seem to increase risk premia, in the case of treasury bills. In other words, the bigger the difference between two bonds, the lower the prediction error for the shorter bonds. This would imply that a large yield spread is associated with high risk premia. It should be noted that a very small spread implies the expectation of a fall in short rates[41]. Of course, this fact is already taken into account by the market, but the uncertainty could make the shorter bond more attractive compared to the long one, in other words a boost of the risk premium. Again, the opposite is true for bonds. A high spread implies a low premium.

8.3 Comments and conclusions

The analysis of government bonds is less reliable than the analysis of treasury bills, largely due to the longer maturities of bonds, making predictions more difficult. Indeed, simply the fact that so few yield spreads for bonds are stationary speaks against the concept of a constant risk premium, at least on a common-sense level. It can hardly be a coincidence that treasury bill prediction errors are stationary, just like their yield spreads, whereas the prediction errors from the more volatile bonds, on the other hand, are *not* stationary.

Also, it is interesting to see that yield spreads affect risk premia, since the yield spread is what we used to approximate risk premia in the first place. However one must remember that the approximation of the risk premium is merely a constant, while the yield spread is a variable. Also, one must keep in mind that the impact of the yield spread in the regressions is not comparable across different combinations. One might be inclined to believe that the yield spread of a combination such as 3 years – 10 years would have the opposite impact as that of, say, 3 months and 10 months since what boosts short bonds (boosts risk premia) would reduce the desire of long bonds (also boost risk premia). This could be the explanation of why we often get opposite results in the treasury bill analysis as in the government bond analysis. In any case, the yield spreads measure only the spreads of the securities in question, nothing else. And thus, at least ideally, capture only the risk premia of the 3-month bond over the 10-month bond, not over the 10-*year* bond! The parameter must be interpreted of the *alternative maturity* in mind, in this case a 10-month bond.

41 See section 3.5.2.

In conclusion, it seems quite clear, given the assumptions made, that factors that plausibly would affect the risk of bonds also indeed do affect the risk premia of investors on the Swedish money market. The risk premia are in other words *not* constant over time, but rather move to some degree with the components of the information set. I've tried to motivate and explain the results of the regression analysis. Of course it should be kept in mind, that all explanations are secondary to showing that risk premia are non-constant, after all. And this has been done. The motivations of the impact of different factors of the information set are first and foremost made to objectively motivate the inclusion of these factors in the *information set*, which is always subject to the arbitrary preferences of the researcher.

In any event, it is difficult to make any more specific statements regarding to what extent these premia are affected, and in what patterns that they move. Does it depend on maturity, yield level, etc? Are there any other factors explaining the movements of the premia? Are there ways of finding out more while at the same time relaxing any assumptions? These are issues that I'll leave to other researchers to deal with.

8.4 Plausible shortcomings of the model

It is possible that our analysis may have benefited from a more linear version of the expectations theory. There does exist such models. For example, Campbell & Shiller (1989) expressed the ET relationship as[42]

$$R_t^{(n)} = (1/k)\sum_{i=0}^{k-n} E_t R_{t+mi}^{(m)} + c \qquad \text{(Equation 31)}$$

Where all yields, R_t, are expressed in logs. This log model is often used as an alternative to the standard version. This would perhaps be a way of confronting the problem of interpreting the impact of the risk premia.

Also, it can certainly not be ruled out that some component affecting the risk premium has been left out by me. This is the problem when trying to arbitrarily model an information set that is relevant.

42 Campbell & Schiller, p. 496

8.5 Suggestion for future studies

- Handling the plausible shortcomings of the model addressed in the previous section is of course good suggestions for future studies. Improving the model and the information set could be ways of performing a deeper study.
- Future model could try to find ways of explaining the large parts of the prediction errors that are not explained by the expectations theory or moving risk premia. These parts are substantial.
- Of course, performing this study for other countries and comparing would be interesting.
- Is the yield spread, non-constant by nature, a better measure of the risk premium?
- Future models need to focus more on expectations models.
- Another way of modelling the information set could be the rigorous "Test, test, test" method of starting out with a large number of variables and then omitting the ones that do not fit the data.

References

Articles:

Campbell, John Y - Shiller, Robert J, 1991, *Yield spreads and interest rate movements: A bird's eye view*, Review of economic studies vol. 58 p. 495 – 514.

Fama, Eugene F, 1991, *Efficient Capital Markets*, The Journal of finance, vol. 46, p. 1575.

Fama, Eugene F, 1984, *Forward and spot exchange rates*, Journal of monetary economics, vol. 14. p. 319 – 338.

Muth, John F, 1961, *Rational expectations and the theory of price movements,* Econometrica, vol. 29. p. 315 – 335.

Literature:

Blanchard, Olivier, 2003. *Macroeconomics*. Prentice hall.

Campbell, John Y – Lo, Andrew W – MacKinlay, Craig A, 1997, *The econometrics of financial markets,* Princeton university press.

Franses, Philip Hans, 1998, *Time series models for business and economic forecasting*, Cambridge university press.

Hamilton, James D, 1994, *Time series analysis,* Princeton university press.

Hill, Carter R – Griffiths, William E – Judge, George G, 2001, *Undergraduate econometrics*, Wiley.

Holme, Solvang, 1997, *Forskningsmetodik*, Studentlitteratur, Lund, second edition.

Hull, John C, 2000, *Options, futures and other derivatives*, Prentice-Hall, fourth edition.

Huberman, M – Miles, M, 1994. *Qualitative data analysis,* Sage Publications, USA.

Hässel, Leif – Norman, Marie – Andersson, Christian, 2001. *De finansiella marknaderna i ett internationellt perspektiv,* Kristianstad, SNS förlag.

Lee, Cheng F – Lee, John C – Lee, Alice C, 2000, *Statistics for business and financial economics*, World Scientific Publishing.

Nicholson, Walter, 2002, *Microeconomic theory,* South-Western, Eighth edition.

Ross, Stephen A– Westerfield Randolph, W – Jaffe, J., 2002, *Corporate Finance*, McGraw-Hill Irwin, Sixth Edition.

Södersten, Bo (ed), 2000, *Marknad och politik*, SNS Förlag.

Verbeek, Marno, 2004, *A guide to modern econometrics*, 2nd ed., Wiley.

Press:

Wall Street Journal, European edition, 2004-04-21

Electronic sources:

EcoWin - Electronic database

Other references:

The information department of the Swedish central bank:
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Appendix

Table A.1 - Double-sided student's t-test for ξ = 0, treasury bills

	Prediction error	*Mean no premium*			*Mean standard premium*			*Mean double premium*		
1	ξ[E(r9,t+1)]	0,001088	11,27522	(***)	0,000642	6,6532089	(***)	0,00020	2,02083	(***)
2	ξ[E(r10,t+1)]	0,000747	8,1269498	(***)	0,000571	6,2121664	(***)	0,00040	4,29738	(***)
3	ξ[E(r11,t+1)]	0,00069	8,2276189	(***)	0,000554	6,6059433	(***)	0,00042	4,98427	(***)
4	ξ[E(r3,t+2)]	0,002458	17,364986	(***)	0,002071	14,630954	(***)	0,00168	11,89692	(***)
5	ξ[E(r4,t+2)]	0,001983	14,683034	(***)	0,001711	12,669022	(***)	0,00144	10,65501	(***)
6	ξ[E(r5,t+2)]	0,002101	16,418032	(***)	0,001778	13,893985	(***)	0,00146	11,36994	(***)
7	ξ[E(r6,t+2)]	0,002113	16,927349	(***)	0,001709	13,690884	(***)	0,00131	10,45442	(***)
8	ξ[E(r7,t+2)]	0,00175	14,577616	(***)	0,001346	11,212269	(***)	0,00094	7,84692	(***)
9	ξ[E(r8,t+2)]	0,00219	17,786718	(***)	0,001497	12,158318	(***)	0,00080	6,52992	(***)
10	ξ[E(r9,t+2)]	0,002078	17,432188	(***)	0,001455	12,205887	(***)	0,00083	6,98798	(***)
11	ξ[E(r10,t+2)]	0,00172	15,084429	(***)	0,001408	12,348184	(***)	0,00110	9,62071	(***)
12	ξ[E(r1,t+3)]	0,007457	22,525171	(***)	0,007986	24,123108	(***)	0,00851	25,71802	(***)
13	ξ[E(r2,t+3)]	0,005106	21,566873	(***)	0,004719	19,932251	(***)	0,00433	18,29763	(***)
14	ξ[E(r3,t+3)]	0,004176	23,819423	(***)	0,003602	20,545393	(***)	0,00303	17,27136	(***)
15	ξ[E(r4,t+3)]	0,006143	34,668329	(***)	0,005655	31,914277	(***)	0,00517	29,16022	(***)
16	ξ[E(r5,t+3)]	0,003716	22,259151	(***)	0,003204	19,192228	(***)	0,00269	16,12531	(***)
17	ξ[E(r6,t+3)]	0,003407	19,654241	(***)	0,002796	16,129515	(***)	0,00219	12,60479	(***)
18	ξ[E(r7,t+3)]	0,003448	20,785836	(***)	0,002539	15,306044	(***)	0,00163	9,83228	(***)
19	ξ[E(r8,t+3)]	0,003281	20,639636	(***)	0,002412	15,173057	(***)	0,00154	9,70648	(***)
20	ξ[E(r9,t+3)]	0,003451	23,117031	(***)	0,002612	17,496866	(***)	0,00177	11,87670	(***)
21	ξ[E(r1,t+4)]	0,012166	27,926797	(***)	0,012529	28,760056	(***)	0,01289	29,59561	(***)
22	ξ[E(r2,t+4)]	0,007829	30,573062	(***)	0,007272	28,397919	(***)	0,00671	26,21887	(***)
23	ξ[E(r3,t+4)]	0,006602	32,471305	(***)	0,005892	28,979238	(***)	0,00518	25,49209	(***)
24	ξ[E(r4,t+4)]	0,005739	29,263182	(***)	0,005062	25,811156	(***)	0,00439	22,36423	(***)
25	ξ[E(r5,t+4)]	0,005535	29,495227	(***)	0,004822	25,695751	(***)	0,00411	21,89628	(***)
26	ξ[E(r6,t+4)]	0,005231	28,147658	(***)	0,003926	21,125541	(***)	0,00262	14,10880	(***)
27	ξ[E(r7,t+4)]	0,004741	26,43654	(***)	0,003656	20,386415	(***)	0,00257	14,33629	(***)
28	ξ[E(r8,t+4)]	0,005083	29,798339	(***)	0,003995	23,4201	(***)	0,00291	17,04186	(***)
29	ξ[E(r1,t+5)]	0,016528	55,843367	(***)	0,016583	56,029196	(***)	0,01664	56,21840	(***)
30	ξ[E(r2,t+5)]	0,011584	41,460463	(***)	0,01098	39,298678	(***)	0,01038	37,13689	(***)
31	ξ[E(r3,t+5)]	0,009317	41,944498	(***)	0,008419	37,901763	(***)	0,00752	33,85453	(***)
32	ξ[E(r4,t+5)]	0,008309	38,904734	(***)	0,007436	34,817139	(***)	0,00656	30,73423	(***)
33	ξ[E(r5,t+5)]	0,007324	36,356894	(***)	0,005892	29,248337	(***)	0,00446	22,13978	(***)
34	ξ[E(r6,t+5)]	0,006832	35,77696	(***)	0,005352	28,026682	(***)	0,00387	20,27117	(***)
35	ξ[E(r7,t+5)]	0,006966	37,393425	(***)	0,005689	30,5385	(***)	0,00441	23,68358	(***)
36	ξ[E(r1,t+6)]	0,026212	53,482907	(***)	0,026253	53,566563	(***)	0,02629	53,64818	(***)
37	ξ[E(r2,t+6)]	0,026783	63,10431	(***)	0,026824	63,200911	(***)	0,02687	63,29751	(***)
38	ξ[E(r3,t+6)]	0,012623	46,211008	(***)	0,011532	42,217012	(***)	0,01044	38,22302	(***)
39	ξ[E(r4,t+6)]	0,010273	40,752286	(***)	0,008643	34,286188	(***)	0,00701	27,82009	(***)
40	ξ[E(r5,t+6)]	0,009148	39,580211	(***)	0,007541	32,627281	(***)	0,00593	25,67003	(***)
41	ξ[E(r6,t+6)]	0,008944	41,014768	(***)	0,0074	33,934401	(***)	0,00586	26,85403	(***)
42	ξ[E(r1,t+7)]	0,034722	59,23567	(***)	0,033775	57,62009	(***)	0,03283	56,00280	(***)
43	ξ[E(r2,t+7)]	0,020731	54,723357	(***)	0,019783	52,220934	(***)	0,01884	49,71851	(***)
44	ξ[E(r3,t+7)]	0,015118	53,834546	(***)	0,013193	46,979704	(***)	0,01127	40,12130	(***)
45	ξ[E(r4,t+7)]	0,012611	48,914696	(***)	0,010805	41,909705	(***)	0,00900	34,90471	(***)
46	ξ[E(r5,t+7)]	0,012507	51,346141	(***)	0,010907	44,777513	(***)	0,00931	38,20889	(***)

	Prediction error	Mean no premium			Mean standard premium			Mean double premium		
47	ξ[E(r1,t+8)]	0,039514	51,945521	(***)	0,039191	51,520901	(***)	0,03887	51,09497	(***)
48	ξ[E(r2,t+8)]	0,024308	60,384697	(***)	0,022513	55,925649	(***)	0,02072	51,46660	(***)
49	ξ[E(r3,t+8)]	0,018506	62,340652	(***)	0,0143	48,047231	(***)	0,01010	33,83597	(***)
50	ξ[E(r4,t+8)]	0,017426	62,131193	(***)	0,015661	55,838208	(***)	0,01390	49,54522	(***)
51	ξ[E(r1,t+9)]	0,054533	74,01357	(***)	0,053237	72,254606	(***)	0,05194	70,49564	(***)
52	ξ[E(r2,t+9)]	0,028764	70,029705	(***)	0,026793	65,231049	(***)	0,02482	60,43239	(***)
53	ξ[E(r3,t+9)]	0,020861	64,953317	(***)	0,018802	58,542365	(***)	0,01674	52,12830	(***)
54	ξ[E(r1,t+10)]	0,060183	67,779194	(***)	0,058711	66,1214	(***)	0,05724	64,46361	(***)
55	ξ[E(r2,t+10)]	0,03388	66,035673	(***)	0,0319	62,176445	(***)	0,02992	58,31917	(***)
56	ξ[E(r1,t+11)]	0,071556	69,130157	(***)	0,070393	68,006585	(***)	0,06923	66,88398	(***)

Table A.2 - Double-sided student's t-test for ξ = 0, government bonds

	Prediction error	Mean no premium			Mean standard premium			Mean double premium		
1	ξE(1Y+1)	0,01543	49,06695458	(***)	0,000547	1,73944421	(***)	-0,014337	-45,59124614	(***)
2	ξE(2Y+1)	0,017396	53,29335841	(***)	-0,009198	-28,17844968	(***)	-0,035791	-109,6471942	(***)
3	ξE(3Y+1)	0,02245	60,89266257	(***)	-0,020913	-56,72375289	(***)	-0,064275	-174,337456	(***)
4	ξE(4Y+1)	0,026221	68,21828657	(***)	-0,028279	-73,57251539	(***)	-0,082779	-215,3633173	(***)
5	ξE(5Y+1)	0,03191	73,07223082	(***)	0,006144	14,06943861	(***)	-0,019621	-44,93106365	(***)
6	ξE(6Y+1)	0,037353	78,59238738	(***)	-0,052537	-110,5402044	(***)	-0,142427	-299,6727962	(***)
7	ξE(7Y+1)	0,04376	81,73491794	(***)	-0,068185	-127,3559273	(***)	-0,180131	-336,4486404	(***)
8	ξE(8Y+1)	0,049528	83,94169161	(***)	-0,079501	-134,7409228	(***)	-0,20853	-353,4235372	(***)
9	ξE(1Y+2)	0,028043	72,60518811	(***)	0,00145	3,754146231	(***)	-0,025143	-65,09689565	(***)
10	ξE(2Y+2)	0,033553	77,65119661	(***)	0,004801	11,11088114	(***)	-0,023951	-55,42943433	(***)
11	ξE(1Y+3)	0,04968	91,17067105	(***)	0,006317	11,59269583	(***)	-0,037046	-67,98527938	(***)
12	ξE(2Y+3)	0,053138	92,44338182	(***)	0,010253	17,83699036	(***)	-0,032631	-56,76766142	(***)
13	ξE(1Y+4)	0,06987	112,5676486	(***)	0,01537	24,76262715	(***)	-0,03913	-63,04239431	(***)
14	ξE(2Y+4)	0,076335	112,0809972	(***)	0,016163	23,73177647	(***)	-0,044009	-64,61744421	(***)
15	ξE(1Y+5)	0,096891	130,6707216	(***)	0,022108	29,81565175	(***)	-0,052674	-71,03806949	(***)
16	ξE(1Y+6)	0,123529	135,8963108	(***)	0,033639	37,00682429	(***)	-0,056251	-61,88266219	(***)
17	ξE(1Y+7)	0,168246	174,2947497	(***)	0,0563	58,32408741	(***)	-0,055645	-57,64553897	(***)
18	ξE(2Y+7)	0,172283	182,6051114	(***)	0,059288	62,84016326	(***)	-0,053707	-56,92478492	(***)
19	ξE(1Y+8)	0,198218	187,0563332	(***)	0,153802	145,1414006	(***)	0,109386	103,2264681	(***)
20	ξE(1Y+9)	0,241792	146,7979122	(***)	0,189504	115,0525723	(***)	0,137215	83,30662522	(***)

Table A.3 Regression analysis, treasury bills

	1		2		3		4		5		6	
PET	u[E(r9,t+1)]	p-value	u[E(r10,t+1)]	p-value	u[E(r11,t+1)]	p-value	u[E(r3,t+2)]	p-value	u[E(r4,t+2)]	p-value	u[E(r5,t+2)]	p-value
OBS	-2.73E-07	0.0052	-4.80E-07	0.0000	-4.51E-07	0.0000	-7.19E-08	0.5781	-2.90E-07	0.0192	-7.52E-08	0.5327
INFL	0.013489	0.0000	0.016123	0.0000	0.012869	0.0000	0.041206	0.0000	0.037483	0.0000	0.029193	0.0000
DUMMY	0.002283	0.0000	0.002643	0.0000	0.002567	0.0000	0.002081	0.0000	0.002689	0.0000	0.002252	0.0000
spread1	1.28E-06	0.0182	-1.06E-06	0.0653	2.01E-06	0.0001	-3.83E-06	0.0000	-3.77E-06	0.0000	1.27E-07	0.8495
Standard	u[E(r9,t+1)]	p-value	u[E(r10,t+1)]	p-value	u[E(r11,t+1)]	p-value	u[E(r3,t+2)]	p-value	u[E(r4,t+2)]	p-value	u[E(r5,t+2)]	p-value
OBS	-3.49E-07	0.0004	-5.10E-07	0.0000	-4.75E-07	0.0000	-1.35E-07	0.2943	-3.35E-07	0.0068	-1.28E-07	0.2867
INFL	0.009740	0.0006	0.014645	0.0000	0.011729	0.0000	0.037385	0.0000	0.034794	0.0000	0.026003	0.0000
DUMMY	0.002196	0.0000	0.002608	0.0000	0.002540	0.0000	0.002005	0.0001	0.002635	0.0000	0.002188	0.0000
spread1	1.28E-06	0.0186	-1.07E-06	0.0644	2.01E-06	0.0001	-3.83E-06	0.0000	-3.77E-06	0.0000	1.54E-07	0.8187
Double	u[E(r9,t+1)]	p-value	u[E(r10,t+1)]	p-value	u[E(r11,t+1)]	p-value	u[E(r3,t+2)]	p-value	u[E(r4,t+2)]	p-value	u[E(r5,t+2)]	p-value
OBS	-4.25E-07	0.0000	-5.40E-07	0.0000	-4.98E-07	0.0000	-1.99E-07	0.1231	-3.80E-07	0.0022	-1.81E-07	0.1318
INFL	0.005990	0.0344	0.013166	0.0000	0.010588	0.0000	0.033564	0.0000	0.032105	0.0000	0.022812	0.0000
DUMMY	0.002109	0.0000	0.002574	0.0000	0.002514	0.0000	0.001928	0.0001	0.002581	0.0000	0.002124	0.0000
spread1	1.27E-06	0.0191	-1.07E-06	0.0635	2.01E-06	0.0001	-3.83E-06	0.0000	-3.77E-06	0.0000	1.80E-07	0.7882

	7		8		9		10		11		12	
PET	u[E(r6,t+2)]	p-value	u[E(r7,t+2)]	p-value	u[E(r8,t+2)]	p-value	u[E(r9,t+2)]	p-value	u[E(r10,t+2)]	p-value	u[E(r1,t+3)]	p-value
PET	-5.54E-08	0.6429	-3.56E-07	0.0013	1.27E-07	0.2396	1.03E-07	0.3384	-1.54E-07	0.1546	-2.02E-06	0.0000
OBS	0.029814	0.0000	0.030903	0.0000	0.021462	0.0000	0.019666	0.0000	0.020436	0.0000	0.187097	0.0000
INFL	0.002122	0.0000	0.002824	0.0000	0.001689	0.0000	0.001785	0.0000	0.002354	0.0000	0.010402	0.0000
DUMMY	-1.05E-06	0.1083	-2.07E-08	0.9757	2.97E-06	0.0000	-1.17E-06	0.0746	-1.81E-07	0.7514	-1.61E-05	0.0000
spread1												
	u[E(r6,t+2)]	p-value	u[E(r7,t+2)]	p-value	u[E(r8,t+2)]	p-value	u[E(r9,t+2)]	p-value	u[E(r10,t+2)]	p-value	u[E(r1,t+3)]	p-value
Standard	-1.22E-07	0.3077	-4.26E-07	0.0001	7.85E-09	0.9421	-3.81E-09	0.9718	-2.07E-07	0.0546	-1.94E-06	0.0000
OBS	0.025821	0.0000	0.027077	0.0000	0.015669	0.0000	0.014458	0.0000	0.017829	0.0000	0.192318	0.0000
INFL	0.002042	0.0000	0.002754	0.0000	0.001557	0.0002	0.001666	0.0001	0.002295	0.0000	0.010514	0.0000
DUMMY	-1.03E-06	0.1126	-4.13E-08	0.9515	2.94E-06	0.0000	-1.19E-06	0.0694	-1.84E-07	0.7468	-1.62E-05	0.0000
spread1												
	u[E(r6,t+2)]	p-value	u[E(r7,t+2)]	p-value	u[E(r8,t+2)]	p-value	u[E(r9,t+2)]	p-value	u[E(r10,t+2)]	p-value	u[E(r1,t+3)]	p-value
Double	-1.88E-07	0.1148	-4.95E-07	0.0000	-1.12E-07	0.3023	-1.11E-07	0.3037	-2.61E-07	0.0155	-1.85E-06	0.0000
OBS	0.021829	0.0000	0.023250	0.0000	0.009876	0.0016	0.009249	0.0030	0.015223	0.0000	0.197539	0.0000
INFL	0.001962	0.0000	0.002684	0.0000	0.001425	0.0005	0.001547	0.0002	0.002235	0.0000	0.010627	0.0000
DUMMY	-1.02E-06	0.1171	-6.18E-08	0.9274	2.90E-06	0.0000	-1.21E-06	0.0646	-1.87E-07	0.7422	-1.63E-05	0.0000

	13		14		15		16		17		18	
PET	u[E(r2,t+3)]	p-value	u[E(r3,t+3)]	p-value	u[E(r4,t+3)]	p-value	u[E(r5,t+3)]	p-value	u[E(r6,t+3)]	p-value	u[E(r7,t+3)]	p-value
OBS	-1.51E-06	0.0000	-5.56E-07	0.0029	-6.20E-07	0.0011	-9.07E-07	0.0000	-5.54E-07	0.0014	-4.31E-07	0.0110
INFL	0.119171	0.0000	0.069897	0.0000	0.117348	0.0000	0.075300	0.0000	0.053284	0.0000	0.048942	0.0000
DUMMY	0.008374	0.0000	0.004843	0.0000	0.005860	0.0000	0.005994	0.0000	0.004895	0.0000	0.004670	0.0000
spread1	-1.22E-05	0.0000	-7.04E-06	0.0000	-5.27E-06	0.0000	-4.50E-06	0.0000	2.21E-06	0.0626	5.15E-07	0.5926
Standard	u[E(r2,t+3)]	p-value	u[E(r3,t+3)]	p-value	u[E(r4,t+3)]	p-value	u[E(r5,t+3)]	p-value	u[E(r6,t+3)]	p-value	u[E(r7,t+3)]	p-value
OBS	-1.58E-06	0.0000	-6.45E-07	0.0005	-7.01E-07	0.0002	-9.96E-07	0.0000	-6.60E-07	0.0001	-5.89E-07	0.0005
INFL	0.115356	0.0000	0.064023	0.0000	0.112544	0.0000	0.070461	0.0000	0.048198	0.0000	0.041379	0.0000
DUMMY	0.008297	0.0000	0.004713	0.0000	0.005765	0.0000	0.005907	0.0000	0.004781	0.0000	0.004500	0.0000
spread1	-1.22E-05	0.0000	-7.02E-06	0.0000	-5.26E-06	0.0000	-4.45E-06	0.0000	2.21E-06	0.0631	4.72E-07	0.6240
Double	u[E(r2,t+3)]	p-value	u[E(r3,t+3)]	p-value	u[E(r4,t+3)]	p-value	u[E(r5,t+3)]	p-value	u[E(r6,t+3)]	p-value	u[E(r7,t+3)]	p-value
OBS	-1.64E-06	0.0000	-7.35E-07	0.0001	-7.81E-07	0.0000	-1.09E-06	0.0000	-7.66E-07	0.0000	-7.47E-07	0.0000
INFL	0.111542	0.0000	0.058150	0.0000	0.107740	0.0000	0.065622	0.0000	0.043113	0.0000	0.033817	0.0000
DUMMY	0.008221	0.0000	0.004583	0.0000	0.005670	0.0000	0.005821	0.0000	0.004668	0.0000	0.004331	0.0000
spread1	-1.22E-05	0.0000	-7.00E-06	0.0000	-5.24E-06	0.0000	-4.40E-06	0.0000	2.21E-06	0.0637	4.29E-07	0.6563

PET	19		20		21		22		23		24	
OBS	u[E(r8,t+3)]	p-value	u[E(r9,t+3)]	p-value	u[E(r1,t+4)]	p-value	u[E(r2,t+4)]	p-value	u[E(r3,t+4)]	p-value	u[E(r4,t+4)]	p-value
INFL	-4.60E-07	0.0061	-7.19E-07	0.0000	-3.49E-06	0.0000	-2.16E-06	0.0000	-9.02E-07	0.0000	-1.01E-06	0.0000
DUMMY	0.046605	0.0000	0.065780	0.0000	0.324901	0.0000	0.190538	0.0000	0.127873	0.0000	0.111694	0.0000
spread1	0.004735	0.0000	0.005381	0.0000	0.016356	0.0000	0.011242	0.0000	0.007251	0.0000	0.007309	0.0000
	6.67E-07	0.4955	1.20E-06	0.1540	-1.49E-05	0.0000	-1.27E-05	0.0000	-9.00E-06	0.0000	-6.77E-06	0.0000
Standard												
OBS	u[E(r8,t+3)]	p-value	u[E(r9,t+3)]	p-value	u[E(r1,t+4)]	p-value	u[E(r2,t+4)]	p-value	u[E(r3,t+4)]	p-value	u[E(r4,t+4)]	p-value
INFL	-6.11E-07	0.0003	-8.64E-07	0.0000	-3.43E-06	0.0000	-2.25E-06	0.0000	-1.02E-06	0.0000	-1.12E-06	0.0000
DUMMY	0.039366	0.0000	0.057856	0.0000	0.328480	0.0000	0.185049	0.0000	0.120893	0.0000	0.105047	0.0000
spread1	0.004573	0.0000	0.005238	0.0000	0.016432	0.0000	0.011132	0.0000	0.007114	0.0000	0.007179	0.0000
	6.02E-07	0.5387	1.19E-06	0.1555	-1.50E-05	0.0000	-1.26E-05	0.0000	-8.96E-06	0.0000	-6.75E-06	0.0000
Double												
OBS	u[E(r8,t+3)]	p-value	u[E(r9,t+3)]	p-value	u[E(r1,t+4)]	p-value	u[E(r2,t+4)]	p-value	u[E(r3,t+4)]	p-value	u[E(r4,t+4)]	p-value
INFL	-7.62E-07	0.0000	-1.01E-06	0.0000	-3.37E-06	0.0000	-2.35E-06	0.0000	-1.14E-06	0.0000	-1.23E-06	0.0000
DUMMY	0.032126	0.0000	0.049931	0.0000	0.332060	0.0000	0.179560	0.0000	0.113913	0.0000	0.098400	0.0000
spread1	0.004412	0.0000	0.005095	0.0000	0.016508	0.0000	0.011022	0.0000	0.006977	0.0000	0.007050	0.0000
PET	5.37E-07	0.5838	1.18E-06	0.1573	-1.50E-05	0.0000	-1.26E-05	0.0000	-8.92E-06	0.0000	-6.73E-06	0.0000

PET	25		26		27		28		29		30	
OBS	u[E(r5,t+4)]	p-value	u[E(r6,t+4)]	p-value	u[E(r7,t+4)]	p-value	u[E(r8,t+4)]	p-value	u[E(r1,t+5)]	p-value	u[E(r2,t+5)]	p-value
INFL	-1.28E-06	0.0000	-3.34E-07	0.0808	-5.55E-07	0.0036	-6.96E-07	0.0002	-1.23E-06	0.0000	-1.59E-06	0.0000
DUMMY	0.120172	0.0000	0.075168	0.0000	0.073545	0.0000	0.087050	0.0000	0.414981	0.0000	0.250559	0.0000
spread1	0.007935	0.0000	0.005472	0.0000	0.005916	0.0000	0.006151	0.0000	0.005497	0.0000	0.010969	0.0000
	-2.91E-06	0.0115	1.76E-06	0.1033	-1.17E-06	0.3031	2.20E-06	0.0135	-1.69E-05	0.0000	-1.28E-05	0.0000
Standard												
OBS	u[E(r5,t+4)]	p-value	u[E(r6,t+4)]	p-value	u[E(r7,t+4)]	p-value	u[E(r8,t+4)]	p-value	u[E(r1,t+5)]	p-value	u[E(r2,t+5)]	p-value
INFL	-1.41E-06	0.0000	-5.63E-07	0.0033	-7.46E-07	0.0001	-8.78E-07	0.0000	-1.22E-06	0.0000	-1.69E-06	0.0000
DUMMY	0.113453	0.0000	0.064356	0.0000	0.064554	0.0000	0.076363	0.0000	0.415526	0.0000	0.244625	0.0000
spread1	0.007816	0.0000	0.005236	0.0000	0.005721	0.0000	0.005943	0.0000	0.005509	0.0000	0.010852	0.0000
	-2.87E-06	0.0127	1.74E-06	0.1068	-1.25E-06	0.2698	2.16E-06	0.0150	-1.69E-05	0.0000	-1.27E-05	0.0000
Double												
OBS	u[E(r5,t+4)]	p-value	u[E(r6,t+4)]	p-value	u[E(r7,t+4)]	p-value	u[E(r8,t+4)]	p-value	u[E(r1,t+5)]	p-value	u[E(r2,t+5)]	p-value
INFL	-1.53E-06	0.0000	-7.92E-07	0.0000	-9.37E-07	0.0000	-1.06E-06	0.0000	-1.21E-06	0.0000	-1.79E-06	0.0000
DUMMY	0.106734	0.0000	0.053545	0.0000	0.055564	0.0000	0.065675	0.0000	0.416071	0.0000	0.238690	0.0000
spread1	0.007698	0.0000	0.004999	0.0000	0.005525	0.0000	0.005735	0.0000	0.005521	0.0000	0.010736	0.0000
PET	-2.83E-06	0.0139	1.73E-06	0.1107	-1.34E-06	0.2393	2.13E-06	0.0167	-1.69E-05	0.0000	-1.27E-05	0.0000

	31		32		33		34		35		36	
PET	u[E(r3,t+5)]	p-value	u[E(r4,t+5)]	p-value	u[E(r5,t+5)]	p-value	u[E(r6,t+5)]	p-value	u[E(r7,t+5)]	p-value	u[E(r1,t+6)]	p-value
OBS	-8.39E-07	0.0003	-1.48E-06	0.0000	-1.72E-07	0.4033	-2.13E-07	0.2937	-6.69E-07	0.0013	-2.37E-06	0.0000
INFL	0.180983	0.0000	0.179165	0.0000	0.107447	0.0000	0.097948	0.0000	0.119116	0.0000	0.604095	0.0000
DUMMY	0.007798	0.0000	0.009527	0.0000	0.006000	0.0000	0.005995	0.0000	0.006922	0.0000	0.016115	0.0000
spread1	-9.98E-06	0.0000	-6.37E-06	0.0000	-2.06E-06	0.0854	-5.24E-07	0.7030	1.75E-06	0.0712	-1.96E-05	0.0000
Standard	u[E(r3,t+5)]	p-value	u[E(r4,t+5)]	p-value	u[E(r5,t+5)]	p-value	u[E(r6,t+5)]	p-value	u[E(r7,t+5)]	p-value	u[E(r1,t+6)]	p-value
OBS	-9.89E-07	0.0000	-1.63E-06	0.0000	-4.26E-07	0.0384	-4.75E-07	0.0190	-8.84E-07	0.0000	-2.36E-06	0.0000
INFL	0.172164	0.0000	0.170971	0.0000	0.095631	0.0000	0.085724	0.0000	0.106602	0.0000	0.604496	0.0000
DUMMY	0.007627	0.0000	0.009385	0.0000	0.005747	0.0000	0.005732	0.0000	0.006682	0.0000	0.016123	0.0000
spread1	-9.93E-06	0.0000	-6.37E-06	0.0000	-2.06E-06	0.0847	-6.00E-07	0.6623	1.72E-06	0.0765	-1.96E-05	0.0000
Double	u[E(r3,t+5)]	p-value	u[E(r4,t+5)]	p-value	u[E(r5,t+5)]	p-value	u[E(r6,t+5)]	p-value	u[E(r7,t+5)]	p-value	u[E(r1,t+6)]	p-value
OBS	-1.14E-06	0.0000	-1.78E-06	0.0000	-6.80E-07	0.0009	-7.37E-07	0.0003	-1.10E-06	0.0000	-2.35E-06	0.0000
INFL	0.163346	0.0000	0.162778	0.0000	0.083815	0.0000	0.073501	0.0000	0.094089	0.0000	0.604896	0.0000
DUMMY	0.007457	0.0000	0.009243	0.0000	0.005494	0.0000	0.005469	0.0000	0.006442	0.0000	0.016132	0.0000
spread1	-9.88E-06	0.0000	-6.37E-06	0.0000	-2.06E-06	0.0842	-6.76E-07	0.6228	1.68E-06	0.0824	-1.96E-05	0.0000

	37		38		39		40		41		42	
PET	u[E(r2,t+6)]	p-value	u[E(r3,t+6)]	p-value	u[E(r4,t+6)]	p-value	u[E(r5,t+6)]	p-value	u[E(r6,t+6)]	p-value	u[E(r1,t+7)]	p-value
OBS	-1.02E-06	0.0118	-1.81E-06	0.0000	-3.22E-07	0.2179	-3.81E-07	0.1249	-1.32E-07	0.5894	-2.98E-06	0.0000
INFL	0.598276	0.0000	0.283626	0.0000	0.169556	0.0000	0.147013	0.0000	0.136195	0.0000	0.834650	0.0000
DUMMY	0.010968	0.0000	0.011882	0.0000	0.007909	0.0000	0.007732	0.0000	0.006537	0.0000	0.019736	0.0000
spread1	-2.29E-05	0.0000	-9.80E-06	0.0000	-6.14E-06	0.0000	-4.77E-06	0.0059	3.17E-06	0.0094	-1.39E-05	0.0000
Standard	u[E(r2,t+6)]	p-value	u[E(r3,t+6)]	p-value	u[E(r4,t+6)]	p-value	u[E(r5,t+6)]	p-value	u[E(r6,t+6)]	p-value	u[E(r1,t+7)]	p-value
OBS	-1.02E-06	0.0123	-2.01E-06	0.0000	-6.14E-07	0.0188	-6.69E-07	0.0071	-3.87E-07	0.1133	-3.14E-06	0.0000
INFL	0.598676	0.0000	0.273407	0.0000	0.156161	0.0000	0.133801	0.0000	0.120833	0.0000	0.825778	0.0000
DUMMY	0.010976	0.0000	0.011708	0.0000	0.007628	0.0000	0.007454	0.0000	0.006232	0.0000	0.019572	0.0000
spread1	-2.29E-05	0.0000	-9.77E-06	0.0000	-6.14E-06	0.0000	-4.83E-06	0.0053	3.16E-06	0.0094	-1.38E-05	0.0000
Double	u[E(r2,t+6)]	p-value	u[E(r3,t+6)]	p-value	u[E(r4,t+6)]	p-value	u[E(r5,t+6)]	p-value	u[E(r6,t+6)]	p-value	u[E(r1,t+7)]	p-value
OBS	-1.01E-06	0.0130	-2.20E-06	0.0000	-9.05E-07	0.0005	-9.56E-07	0.0001	-6.42E-07	0.0086	-3.31E-06	0.0000
INFL	0.599076	0.0000	0.263188	0.0000	0.142765	0.0000	0.120589	0.0000	0.105471	0.0000	0.816906	0.0000
DUMMY	0.010984	0.0000	0.011533	0.0000	0.007347	0.0000	0.007176	0.0000	0.005927	0.0000	0.019409	0.0000
spread1	-2.29E-05	0.0000	-9.73E-06	0.0000	-6.14E-06	0.0000	-4.89E-06	0.0047	3.15E-06	0.0096	-1.37E-05	0.0000

	43		44		45		46		47		48	
PET	u[E(r2,t+7)]	p-value	u[E(r3,t+7)]	p-value	u[E(r4,t+7)]	p-value	u[E(r5,t+7)]	p-value	u[E(r1,t+8)]	p-value	u[E(r2,t+8)]	p-value
OBS	-2.53E-06	0.0000	2.53E-07	0.3753	-4.92E-08	0.8589	-3.85E-07	0.1633	-2.10E-07	0.7652	1.21E-06	0.0031
INFL	0.499530	0.0000	0.268382	0.0000	0.212818	0.0000	0.222394	0.0000	0.888876	0.0000	0.452086	0.0000
DUMMY	0.014832	0.0000	0.006957	0.0000	0.007531	0.0000	0.007934	0.0000	0.010776	0.0000	0.005983	0.0001
spread1	-1.58E-05	0.0000	-1.24E-05	0.0000	-1.06E-05	0.0000	-4.88E-07	0.7171	-2.68E-05	0.0000	-1.32E-05	0.0000
Standard	u[E(r2,t+7)]	p-value	u[E(r3,t+7)]	p-value	u[E(r4,t+7)]	p-value	u[E(r5,t+7)]	p-value	u[E(r1,t+8)]	p-value	u[E(r2,t+8)]	p-value
OBS	-2.70E-06	0.0000	-9.38E-08	0.7413	-3.75E-07	0.1747	-6.57E-07	0.0169	-2.68E-07	0.7035	8.85E-07	0.0295
INFL	0.490666	0.0000	0.252616	0.0000	0.198029	0.0000	0.206767	0.0000	0.886223	0.0000	0.437414	0.0000
DUMMY	0.014680	0.0000	0.006631	0.0000	0.007227	0.0000	0.007642	0.0000	0.010719	0.0000	0.005681	0.0002
spread1	-1.58E-05	0.0000	-1.23E-05	0.0000	-1.06E-05	0.0000	-4.31E-07	0.7479	-2.68E-05	0.0000	-1.30E-05	0.0000
Double	u[E(r2,t+7)]	p-value	u[E(r3,t+7)]	p-value	u[E(r4,t+7)]	p-value	u[E(r5,t+7)]	p-value	u[E(r1,t+8)]	p-value	u[E(r2,t+8)]	p-value
OBS	-2.87E-06	0.0000	-4.40E-07	0.1201	-7.00E-07	0.0110	-9.29E-07	0.0007	-3.25E-07	0.6437	5.61E-07	0.1664
INFL	0.481801	0.0000	0.236849	0.0000	0.183239	0.0000	0.191140	0.0000	0.883569	0.0000	0.422742	0.0000
DUMMY	0.014529	0.0000	0.006306	0.0000	0.006923	0.0000	0.007350	0.0000	0.010661	0.0000	0.005379	0.0004
spread1	-1.57E-05	0.0000	-1.23E-05	0.0000	-1.06E-05	0.0000	-3.74E-07	0.7796	-2.68E-05	0.0000	-1.29E-05	0.0000

	49		50		51		52		53		54	
PET	u[E(r3,t+8)]	p-value	u[E(r4,t+8)]	p-value	u[E(r1,t+9)]	p-value	u[E(r2,t+9)]	p-value	u[E(r3,t+9)]	p-value	u[E(r1,t+10)]	p-value
OBS	1.13E-06	0.0004	2.13E-07	0.5065	3.25E-06	0.0000	2.88E-06	0.0000	1.95E-06	0.0000	3.33E-06	0.0001
INFL	0.310178	0.0000	0.309657	0.0000	1.078228	0.0000	0.541163	0.0000	0.375535	0.0000	1.273386	0.0000
DUMMY	0.005120	0.0000	0.007070	0.0000	-0.001892	0.3654	-0.000587	0.6821	0.001366	0.2698	0.002482	0.4325
spread1	-1.59E-05	0.0000	-3.04E-06	0.0331	-3.18E-05	0.0000	-2.03E-05	0.0000	-1.13E-05	0.0000	-3.85E-05	0.0000
Standard	u[E(r3,t+8)]	p-value	u[E(r4,t+8)]	p-value	u[E(r1,t+9)]	p-value	u[E(r2,t+9)]	p-value	u[E(r3,t+9)]	p-value	u[E(r1,t+10)]	p-value
OBS	3.42E-07	0.2768	-8.86E-08	0.7806	3.02E-06	0.0000	2.53E-06	0.0000	1.58E-06	0.0000	3.07E-06	0.0003
INFL	0.277824	0.0000	0.292457	0.0000	1.067614	0.0000	0.525062	0.0000	0.358725	0.0000	1.261430	0.0000
DUMMY	0.004416	0.0002	0.006751	0.0000	-0.002121	0.3084	-0.000920	0.5186	0.001025	0.4046	0.002231	0.4793
spread1	-1.59E-05	0.0000	-3.05E-06	0.0316	-3.17E-05	0.0000	-2.02E-05	0.0000	-1.12E-05	0.0000	-3.83E-05	0.0000
Double	u[E(r3,t+8)]	p-value	u[E(r4,t+8)]	p-value	u[E(r1,t+9)]	p-value	u[E(r2,t+9)]	p-value	u[E(r3,t+9)]	p-value	u[E(r1,t+10)]	p-value
OBS	-4.41E-07	0.1574	-3.90E-07	0.2180	2.79E-06	0.0000	2.17E-06	0.0000	1.21E-06	0.0002	2.80E-06	0.0010
INFL	0.245487	0.0000	0.275258	0.0000	1.057000	0.0000	0.508962	0.0000	0.341916	0.0000	1.249473	0.0000
DUMMY	0.003712	0.0014	0.006433	0.0000	-0.002350	0.2572	-0.001252	0.3766	0.000684	0.5759	0.001980	0.5290
spread1	-1.58E-05	0.0000	-3.06E-06	0.0302	-3.15E-05	0.0000	-2.01E-05	0.0000	-1.12E-05	0.0000	-3.82E-05	0.0000

	55		56	
PET	u[E(r2,t+10)]	p-value	u[E(r1,t+11)]	p-value
OBS	2.44E-06	0.0000	4.57E-06	0.0000
INFL	0.638954	0.0000	1.510282	0.0000
DUMMY	0.003405	0.0878	0.001131	0.7524
spread1	-1.04E-05	0.0000	-3.18E-05	0.0000
Standard	u[E(r2,t+10)]	p-value	u[E(r1,t+11)]	p-value
OBS	2.08E-06	0.0001	4.35E-06	0.0000
INFL	0.622891	0.0000	1.500863	0.0000
DUMMY	0.003087	0.1199	0.000939	0.7930
spread1	-1.03E-05	0.0000	-3.17E-05	0.0000
Double	u[E(r2,t+10)]	p-value	u[E(r1,t+11)]	p-value
OBS	1.72E-06	0.0013	4.14E-06	0.0000
INFL	0.606828	0.0000	1.491443	0.0000
DUMMY	0.002769	0.1610	0.000747	0.8343
spread1	-1.02E-05	0.0000	-3.16E-05	0.0000

Table A.4 Regression analysis government bonds

	1		2		3		4		5		6	
PET	*ξE(1Y+1)*	*p-value*	*ξE(2Y+1)*	*p-value*	*ξE(3Y+1)*	*p-value*	*ξE(4Y+1)*	*p-value*	*ξE(5Y+1)*	*p-value*	*ξE(6Y+1)*	*p-value*
DUMMY	-0.000108	0.3380	-0.000202	0.0215	-0.000188	0.0269	-0.000173	0.0451	-0.000171	0.0481	-0.000178	0.0494
ΔINFL	0.033065	0.1677	0.036686	0.0493	0.031576	0.0799	-0.000511	0.9777	0.015766	0.3890	-0.010155	0.5957
OBS	2.34E-08	0.3933	4.83E-08	0.0236	4.39E-08	0.0339	3.91E-08	0.0623	3.83E-08	0.0687	3.91E-08	0.0755
Δspread1	0.012429	0.0000	0.012921	0.0000	0.009169	0.0000	0.007177	0.0000	0.013265	0.0000	0.017477	0.0000
Standard	*ξE(1Y+1)*	*p-value*	*ξE(2Y+1)*	*p-value*	*ξE(3Y+1)*	*p-value*	*ξE(4Y+1)*	*p-value*	*ξE(5Y+1)*	*p-value*	*ξE(6Y+1)*	*p-value*
DUMMY	-0.000108	0.3380	-0.000202	0.0215	-0.000188	0.0269	-0.000173	0.0451	-0.000171	0.0481	-0.000178	0.0494
ΔINFL	0.033065	0.1677	0.036686	0.0493	0.031576	0.0799	-0.000511	0.9777	0.015766	0.3890	-0.010155	0.5957
OBS	2.34E-08	0.3933	4.83E-08	0.0236	4.39E-08	0.0339	3.91E-08	0.0623	3.83E-08	0.0687	3.91E-08	0.0755
Δspread1	0.012429	0.0000	0.012921	0.0000	0.009169	0.0000	0.007177	0.0000	0.013265	0.0000	0.017477	0.0000
Double	*ξE(1Y+1)*	*p-value*	*ξE(2Y+1)*	*p-value*	*ξE(3Y+1)*	*p-value*	*ξE(4Y+1)*	*p-value*	*ξE(5Y+1)*	*p-value*	*ξE(6Y+1)*	*p-value*
DUMMY	-0.000108	0.3380	-0.000202	0.0215	-0.000188	0.0269	-0.000173	0.0451	-0.000171	0.0481	-0.000178	0.0494
ΔINFL	0.033065	0.1677	0.036686	0.0493	0.031576	0.0799	-0.000511	0.9777	0.015766	0.3890	-0.010155	0.5957
OBS	2.34E-08	0.3933	4.83E-08	0.0236	4.39E-08	0.0339	3.91E-08	0.0623	3.83E-08	0.0687	3.91E-08	0.0755
Δspread1	0.012429	0.0000	0.012921	0.0000	0.009169	0.0000	0.007177	0.0000	0.013265	0.0000	0.017477	0.0000

	7		8		9		10		11		12	
PET	*ξE(7Y+1)*	*p-value*	*ξE(8Y+1)*	*p-value*	*ξE(1Y+2)*	*p-value*	*ξE(2Y+2)*	*p-value*	*ξE(1Y+3)*	*p-value*	*ξE(2Y+3)*	*p-value*
DUMMY	-0.000148	0.1242	-0.000134	0.1817	-3.85E-06	0.9789	-5.82E-05	0.4366	3.82E-05	0.8362	-7.54E-05	0.4253
ΔINFL	0.007688	0.7055	-2.44E-05	0.9991	0.020544	0.5073	0.026463	0.0961	-0.076761	0.0504	9.63E-05	0.9962
OBS	3.12E-08	0.1830	2.70E-08	0.2703	-1.92E-09	0.9580	1.45E-08	0.4399	-1.54E-08	0.7458	1.76E-08	0.4686
Δspread1	0.009663	0.0000	0.008840	0.0000	0.006313	0.0000	0.020197	0.0000	0.008327	0.0000	0.019484	0.0000
Standard	*ξE(7Y+1)*	*p-value*	*ξE(8Y+1)*	*p-value*	*ξE(1Y+2)*	*p-value*	*ξE(2Y+2)*	*p-value*	*ξE(1Y+3)*	*p-value*	*ξE(2Y+3)*	*p-value*
DUMMY	-0.000148	0.1242	-0.000134	0.1817	-3.85E-06	0.9789	-5.82E-05	0.4366	3.82E-05	0.8362	-7.54E-05	0.4253
ΔINFL	0.007688	0.7055	-2.44E-05	0.9991	0.020544	0.5073	0.026463	0.0961	-0.076761	0.0504	9.63E-05	0.9962
OBS	3.12E-08	0.1830	2.70E-08	0.2703	-1.92E-09	0.9580	1.45E-08	0.4399	-1.54E-08	0.7458	1.76E-08	0.4686
Δspread1	0.009663	0.0000	0.008840	0.0000	0.006313	0.0000	0.020197	0.0000	0.008327	0.0000	0.019484	0.0000
Double	*ξE(7Y+1)*	*p-value*	*ξE(8Y+1)*	*p-value*	*ξE(1Y+2)*	*p-value*	*ξE(2Y+2)*	*p-value*	*ξE(1Y+3)*	*p-value*	*ξE(2Y+3)*	*p-value*
DUMMY	-0.000148	0.1242	-0.000134	0.1817	-3.85E-06	0.9789	-5.82E-05	0.4366	3.82E-05	0.8362	-7.54E-05	0.4253
ΔINFL	0.007688	0.7055	-2.44E-05	0.9991	0.020544	0.5073	0.026463	0.0961	-0.076761	0.0504	9.63E-05	0.9962
OBS	3.12E-08	0.1830	2.70E-08	0.2703	-1.92E-09	0.9580	1.45E-08	0.4399	-1.54E-08	0.7458	1.76E-08	0.4686
Δspread1	0.009663	0.0000	0.008840	0.0000	0.006313	0.0000	0.020197	0.0000	0.008327	0.0000	0.019484	0.0000

	13		14		15		16		17		18	
PET	*ξE(1Y+4)*	*p-value*	*ξE(2Y+4)*	*p-value*	*ξE(1Y+5)*	*p-value*	*ξE(1Y+6)*	*p-value*	*ξE(1Y+7)*	*p-value*	*ξE(2Y+7)*	*p-value*
DUMMY	-0.000100	0.5388	-0.000167	0.1241	-7.32E-05	0.7311	9.02E-05	0.6525	1.30E-05	0.9699	-0.000151	0.3507
ΔINFL	0.078776	0.0244	0.030868	0.1839	-0.048891	0.2874	0.059062	0.1759	-0.077899	0.3030	0.178984	0.0000
OBS	1.84E-08	0.6693	4.04E-08	0.1573	4.73E-09	0.9343	-4.38E-08	0.4251	-3.24E-08	0.7337	3.46E-08	0.4406
Δspread1	0.008436	0.0000	0.022093	0.0000	0.012514	0.0000	0.009614	0.0000	0.017292	0.0000	0.026765	0.0000
Standard	*ξE(1Y+4)*	*p-value*	*ξE(2Y+4)*	*p-value*	*ξE(1Y+5)*	*p-value*	*ξE(1Y+6)*	*p-value*	*ξE(1Y+7)*	*p-value*	*ξE(2Y+7)*	*p-value*
DUMMY	-0.000100	0.5388	-0.000167	0.1241	-7.32E-05	0.7311	9.02E-05	0.6525	1.30E-05	0.9699	-0.000151	0.3507
ΔINFL	0.078776	0.0244	0.030868	0.1839	-0.048891	0.2874	0.059062	0.1759	-0.077899	0.3030	0.178984	0.0000
OBS	1.84E-08	0.6693	4.04E-08	0.1573	4.73E-09	0.9343	-4.38E-08	0.4251	-3.24E-08	0.7337	3.46E-08	0.4406
Δspread1	0.008436	0.0000	0.022093	0.0000	0.012514	0.0000	0.009614	0.0000	0.017292	0.0000	0.026765	0.0000
Double	*ξE(1Y+4)*	*p-value*	*ξE(2Y+4)*	*p-value*	*ξE(1Y+5)*	*p-value*	*ξE(1Y+6)*	*p-value*	*ξE(1Y+7)*	*p-value*	*ξE(2Y+7)*	*p-value*
DUMMY	-0.000100	0.5388	-0.000167	0.1241	-7.32E-05	0.7311	9.02E-05	0.6525	1.30E-05	0.9699	-0.000151	0.3507
ΔINFL	0.078776	0.0244	0.030868	0.1839	-0.048891	0.2874	0.059062	0.1759	-0.077899	0.3030	0.178984	0.0000
OBS	1.84E-08	0.6693	4.04E-08	0.1573	4.73E-09	0.9343	-4.38E-08	0.4251	-3.24E-08	0.7337	3.46E-08	0.4406
Δspread1	0.008436	0.0000	0.022093	0.0000	0.012514	0.0000	0.009614	0.0000	0.017292	0.0000	0.026765	0.0000

	19		20	
PET	*ξE(1Y+8)*	*p-value*	*ξE(1Y+9)*	*p-value*
DUMMY	0.000137	0.7304	0.000106	0.7886
ΔINFL	0.683498	0.0000	-0.512626	0.0000
OBS	-5.08E-08	0.6428	-5.60E-08	0.5972
Δspread1	0.014478	0.0000	0.016928	0.0000
Standard	*ξE(1Y+8)*	*p-value*	*ξE(1Y+9)*	*p-value*
DUMMY	0.000137	0.7304	0.000106	0.7886
ΔINFL	0.683498	0.0000	-0.512626	0.0000
OBS	-5.08E-08	0.6428	-5.60E-08	0.5972
Δspread1	0.014478	0.0000	0.016928	0.0000
Double	*ξE(1Y+8)*	*p-value*	*ξE(1Y+9)*	*p-value*
DUMMY	0.000137	0.7304	0.000106	0.7886
ΔINFL	0.683498	0.0000	-0.512626	0.0000
OBS	-5.08E-08	0.6428	-5.60E-08	0.5972
Δspread1	0.014478	0.0000	0.016928	0.0000

Graph A.1 - Yields of selected Swedish government bonds and treasury bills