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TESTING THE EXPECTATIONS HYPOTHESIS WITH SURVEY DATA

with an introduction of an analysis of surveyed interest rates

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I INTRODUCTION

This paper is an empirical study of the properties of the term structure of interest rates. It tests statistically to what extent the forward interest rates that are implicit in the term structure can be used as a forecast of the future interest rates, i.e. it tests what is known as the expectations hypothesis of the term structure of interest rates (EH)[1]. It is tested in a great number of articles of Modigliani and Shiller (1973), Shiller (1979), Shiller, Campbell and Schoenholtz (1983), Friedman (1979), Fama (1984), Markiw (1986) and Campbell and Shiller (1987). Gerlach and Smets (1995) tested the EH for 17 countries at the short end of the maturity structure. In about half of cases (including Sweden) they could not reject the EH. USA and Austria are two countries where the EH does not hold. On UK data, MacDonald and Macmillan (1994) do not find support for the EH. In data from the USA it is often found that forward rates are worse predictors of future interest rates than the naive martingale method - that the future interest rate is the same as the interest today[2]. The null hypothesis in most tests of the expectations theory is a joint hypothesis - that the expectations are rational, and that the interest rate differentials between different maturities depend on expected interest rate changes.

The explanation of the rejections of the EH varies from author to author. Most authors argue that the rejections are a consequence of time-varying risk premia. Among those we find Startz (1982), Mankiw and Miron (1986). Authors who reject the EH because of this explanation have often studied interest rates with short maturities. Others suggest that the rejection is due to the market's over- or underreaction in relation to what is rational. Among those Shiller (1981), Campbell and Shiller (1984), Mankiw and Summers (1984) can be mentioned. Their tests support the idea that the rejection of the EH depends on underreaction of long interest rates to short interest rates' changes.

In Sweden, the EH has been tested by Hörngren (1986), Ekdahl and Warne (1990), Dahlquist and Jonnson (1994) and Hördahl (1994). The common feature of these studies is that, with exception of Hörngren's study, they do not reject the EH. Ekdahl and Warne use a VAR-model and Hördahl an ARCH-M model. As this study uses the same model as Hörngren and Dahlquist and Jonsson their results will be more carefully compared to the results in this study.

In testing the EH Froot (1989) goes one step further than all the other authors. He performs the standard test of whether the differential between the implicit forward rate and today's spot rate is an unbiased predictor of future interest rate changes[3]. By decomposing this spread's bias into one component attributable to a risk premium and one component attributable to a systematic expectation error he makes it possible to measure to what extent a time-varying risk premium and an expectation error give the greatest contribution to the rejection of the EH. To be able to do the

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[1] In the literature, the EH is sometimes called the "efficiency-test". However, the EH may or may not hold in an efficient market.

[2] However, Hsu and Kugler (1997) show that the EH cannot be rejected on U.S. data for the last of the four subperiods studied, 1987-1995.

[3] Apart from the standard test, in the literature there are several variants of this model to test the expectations hypothesis. Often either the change in the long-term interest rate or the realized excess holding return is used as the dependent variable, and the spread of the forward premium above the long-term rate is used as the regressor. For a more complete set of univariate regression tests of the expectations hypothesis, see Froot (1987).

decomposition of the spread's bias into the two components a time series of the expected interest rate is required. In this respect Froot uses a survey data set of expected interest rates. At the end of each quarter from mid-1969 to the end of 1986 a survey institute[4] has asked financial market participants about their expectations on interest rates on three-month T-bills, three-month Eurodollar deposits and bonds with longer maturities. Each respondent was asked to give his or her expectation of the level of each of the rates in three and six months' time.

This study uses the standard test of the EH, which makes it is possible, directly, to compare the results in this study with the results of tests made by other authors - in the first place Froot, Hörngren and Dahlquist and Jonsson. This study is not motivated by a concern for interest rate forecasting per se, but it shows how reliable the EH is in forecasting interest rates. If this study shows that the EH cannot be rejected, of course, it gives the actors in the money market a good method for forecasting future interest rates with different maturities. The study follows Froot's method of decomposing the spread's bias into the two components - one attributable to the risk premium and one attributable to the systematic expectation error. In this respect this study deepens previous tests of the EH on Swedish data - particularly Hörngren and Dahlquist and Jonsson's tests. The decomposition is the extra contribution this paper gives the Swedish literature of tests of the EH. The results of this decomposition might indicate a striking difference in the importance of the competing explanations of the U.S.- and Swedish money markets[5]. If our test of the EH on Swedish data shows that the EH cannot be rejected, the decomposition is still interesting to do. It is possible that the decomposition of the forward premia into its two components shows that both the risk premium and the systematic expectation error components are both quite large - but show different signs - so that the EH is not rejected.

In spite of the great importance which has been attributed to interest rate expectations there have been very few attempts, in Sweden, to directly investigate and measure the expectations of future interest rates that different categories are expected to have. The first survey in Sweden was conducted by the news agency Direkt. Since September 1992 it regulary surveyed market actors about their expectations of the future interest rate. Hence, Sweden has for a long time been without an empirical basis to judge many of the arguments that have been carried forward to value monetary policy and investment decisions made by portfolio managers. However, there are methods to indirectly measure the market's interest rate expectations. The basis for these methods is rational expectations - that expectations are not systematically wrong and use all available information. One example of an indirect measure of the expected interest rate is the yield curve - where the implicit forward rate is regarded as a measure of the expected interest rate.
The news agency Direkt's survey of the expected interest rate was the first of this kind in Sweden. Therefore a presentation and analysis of the time series itself is motivated. The purpose of the first part of the paper is to present and analyse the surveyed interest rates. We present the mean surveyed answers and analyse their power to predict the future interest rate. The quantitative analysis uses the level of the answers - the mean - to measure the capacity to forecast future interest rates. In addition to the mean the maximum and minimum surveyed answers are announced. This gives us the opportunity to map the degree of diversity in the survey answers. In theoretical and empirical studies of the term structure of interest rates, as a rule, it is assumed that the studied group has identical interest rate expectations. This question is discussed in relation to the results from the survey.

[4] Froot uses survey data from the Goldsmith-Nagan Bond and Money Market Letter publication.
[5] According to Froot (1989) the rejection of the EH on U.S. data is due to a positive risk premium.

Consequently, the purpose of the paper is to throw light on several questions. Some of them have not been analysed earlier on Swedish data.

The paper is organized as follows. In section II we present and analyse, empirically, the answers to the survey by the news agency Direkt. Section II:1 describes the agency's procedure in surveying financial-market participants. Section II:2 analyses the mean surveyed interest rates and tests the predictive power of the mean surveyed data set. In section II:2.1 we present the survey data and the mean forecast errors and in 2.2 we answer the question if the surveyed forecast errors behave rational. We measure to what extent the mean survey interest rates predicts the actual future interest rates. Section II:2.3 analyses the uncertainty in the survey answers where the uncertainty is measured by the difference between the maximum and minimum surveyed answers. Section III is devoted to distinguish between different forms of the EH. In section IV we present how to test the EH without a direct measure of expectations - the standard test of the EH. We also present the results of this test. Section IV:1 contains a comparison with other tests of the EH on foreign data and in section IV:2 we do Swedish comparisons of tests of the EH. Section V is devoted to the EH with survey data. In section V:1 we show how the so-called forward premium is decomposed and section V:2 performs Froot's (1989) decomposition of the regression coefficient of the difference between the forward rate and today's spot rate into one component attributable to a risk premium and one component attributable to a systematic expectation error. This section is also devoted to the empirical results of the decomposition of the β-coefficient into its two components. In section V:3 we make comparisons with Froot's and other authors who have made the decomposition of the β-coefficient into a time-varying risk premium and an expectation error. The paper ends with conclusions and a summary in section VI.

II PRESENTING AND EXAMINING THE SURVEY DATA

1 The news agency Direkt's measurement of the expected interest rates

Before we present and analyse the Swedish survey data we want to present survey data studies from other countries. Froot (1989) is already mentioned to be the pioneer to perform the standard test of the EH and make the decomposition of the differential between the implicit forward rate and today's spot rate. MacDonald/Macmillan (1994) and Batchelor (1990) perform exactly the same tests as Froot with UK and U.S. data, respectively. To test the unbiasedness of survey data Kim (1996) and Friedman (1980) use Australian and U.S. survey data, respectively. Ferderer/Shadbegian (1993) and Prell (1973) studied the survey forecast errors measured as root mean square error and mean average error. The results from these studies will be compared to the results in this study.

Traditionally, economists have been critical to results from surveys[6]. One argument is that the results from survey do not describe decisions and actions that the respondents actually choose to realize. In this respect the respondents "true" comprehension is not revealed and hence the expectations cannot be measured in a correct way. So, the disadvantage is that the respondents never can be put in a completely realistic decision making context where a correct answer is rewarded and a wrong guess is punished. Another argument is that different survey respondents have different beliefs. If there is one single market expectation the medium survey measures it with error. Froot discusses that the

[6] See Froot (1989) p 285 and Jonung (1990) p 15.

markets expectation should be a complicated weighted average of individual respondents' expectations. A possible measurement error can arise when survey respondents and the corresponding interest rates are not recorded at the same time. From this point of view a method where the respondents' market behaviour, in some way or other, is exposed to the average interest rate expectation is to be preferred. However, such experimental evidence is not available. Lahiri and Zaporowski (1988) studied inflation forecasts from the Livingstone survey. Several studies have found that these data typically underestimate the true[7] market expectations. The authors find that surveyed answers had less predictive accuracy than rational measures. The root mean square prediction error on the Livingstone survey is nearly three times as great as that of the rationally expectation inflation forecasts.[8] These findings make them doubtful on the reliability of the Livingstone survey data.

Survey measurement of interest rate expectations is of two kinds, qualitative and quantitative. The first group is based on surveys where respondents state whether they expect interest rates to rise, stay constant or fall. The second type of measurement of interest rate expectations is based on surveys which ask for direct quantitative measurement of the expected level of the interest rates. This paper describes a survey of expected interest rates in Sweden that belongs to the second category of studies described.

At the end of each month the news agency Direkt *surveyed* financial-market participants about their expected level of the six-month Treasury bill rate ("statsskuldväxel") three- and six months ahead and the expected level of the five- year bond rate six months in the future. The survey started in September 1992. However, the data we present in this study begins in the end of December 1992. There are two reasons why we drop the observations up to December 1992. First, in this study we want to cover the time when Sweden applied a flexible exchange rate regime. Sweden left the fix rate exchange rate regime on November 19, 1992. It is not unrealistic to think that it takes some time both for the market to "settle down" and for market participants to learn how the new system works well enough to avoid systematic errors. Second, the money market was extremely turbulent in autumn 1992, before the central bank had to give up the defence of the fixed exchange rate. The interest rates were very difficult to forecast, so the forecast errors during this time period might not be representative compared to a more normal development of the money market.

The news agency Direkt terminated the survey in the end of January 1996. From March 1996 "Six Markets Estimates" have continued the survey. To be able to compare the survey results with similar studies in other countries they have changed the surveyed interest rate - from the six-month rate to the three-month rate. This means that our data series of surveyed six-month rate three-and six-months ahead end in January 1996.

The survey respondents were analysts and traders in banks and investment companies[9]. In other words the respondents do not cover a broad representative sample but are restricted to a group that

[7] True is in the context of their rational expectations hypothesis (REH) model to estimate inflation expectations.
[8] Lahiri and Zaporowski (1988) also show that the Livingstone series significantly underestimates actual inflation, while inflation expectations estimated by the rational expectations model exhibits no such underestimation.
[9] In the end of October 1994, e.g., the following respondents were asked about the expected future interest rates: Aragon, Consensus, Föreningsbanken, Handelsbanken, Midland Bank, Nordbanken, S-E-Banken, Sparbanken, Transferator, United Securities and Öhman. It was not exactly the same respondents every month. Certain months a few can have been substituted by others.

professionally follow the interest rate development. The news agency Direct sent the survey forms at the end of each month. The respondents answered on average two days after the send out. The send out was made by fax and the answers were also made by fax or by telephone, not ordinary mail. The send out dates vary from month to month. The forms were sent out between the 20th and the 28th each month (during the summer months between the 8th and the 11th). We date the replys two days after that day, i.e. if the send out was made September 28, 1993, the ”reply date” is September 30, 1993. The actual interest rates, spot and forward, are of course taken from the same day - September 30, 1993, and three- and six months ahead.

As the date of the send out varies from month to month the time series of the actual six-month rate three months ahead and the actual six-month rate six months ahead (lagged three times) are not exactly identical. Suppose the send out in December is made December 20, 1993 and the answer is received December 22, 1993. The actual three months ahead rate is on March 22, 1994, which is different from the actual six months ahead rate March 30, 1994 (six months after the answer received September 30, 1993). This is the explanation why the actual three- and six months ahead rates are not identical in Figures 2a and 2b.

The mean expected interest rates were then announced as the “market's expected interest rates”. In addition to the mean the maximum and minimum answers were announced. Unfortunately we do not have access to each respondent's answer so it is not possible to analyse the statistical distribution of the survey answers.

Some observations in the survey data set are simply unavailable for reasons unknown to the author. The missing values have not been replaced. Griliches (1986) calls this the ignorable case[10], in that for purposes of estimation, if we are not concerned with efficiency, we may simply ignore the problem. The missing observations are displayed in Table 1.

The dataset of the *actual* interest rates consists of monthly observations for Swedish T-bills (“statsskuldväxlar”) with 3, 6, 9 and 12 months to maturity. We need the last two maturities to be able to calculate the implicit forward rates. The sample period covers the time from December 1992 to January 1996 providing 38 observations in total. We have had access to daily observations.

The actual-and expected interest rates are quoted as annualized simple interest rates. From these we compute continuously compounded interest rates and forward rates[11]. The term structure of interest rates observed in our data is plotted against time to maturity in Figure 1. The yield curve has a negative slope until mid 1994 when it turns to a positive slope. In mid 1995 it is horizontal but

[10] Griliches (1986) distinguishes between three types of missing observations: undercoverage, unit non-response, and item non-response. The first type relates to the possibility that a certain fraction of the population is excluded from the sample by accident or design. The unit non-response relates to the refusal of a respondent to answer a questionnaire or the inability of the interviewer to find it. Item non-response is used when responses are missing for some fraction of the sample, i.e., questions not answered, items not filled in, in a larger data collection effort. The discussion deals with randomly missing observations or the notion of the ignorable case in another terminology. Given the assumption of a constant β irrespective of the level of the explanatory variable, x, the observations can be missing “non-randomly” as long as the conditional expectation of y for a given x does not depend on which x's are missing. For example, there is nothing wrong if all “high” x's are missing, provided the error term and x are uncorrelated over the whole range of the data.

[11] In the Appendix we illustrate how continuously compounded interest rates and implicit forward rates are calculated.

receives a negative slope at the end of the year. Figure 1 also shows that the interest rates have decreased from December 1992 to the end of 1993. The interest rates have increased from the beginning of 1994 to mid 1995 and then decreased again to January 1996.

2 The predictive power of the mean surveyed interest rate

2.1 Presenting the survey data and the mean surveyed forecast errors

Figures 2a,b display the actual- and mean surveyed interest rates of the six-month rate three- and six months ahead, respectively. The dating is such that the numbers for month t refer to the expectation held at t with respect to t+3 (or t+6) and the actual rate at t+3 (or t+6), respectively. When the actual interest rate decreases (increases) the mean interest rates expectations tend to be above (under) the actual interest rates.

How good are the respondents at estimating the future interest rates? What accuracy is there in the interest rate expectations? This is illustrated in Figures 3a,b where we put correct expectations along the 45°-line, where the actual interest rates coincide with the expected. Observations above the 45°-line represent overestimations of the interest rates in the surveys, points under it represent underestimations of the actual development. Figure 3a shows that the respondents both have over- and underestimated the future six-month rate three months ahead. Of the 32 mean surveyed observations during the time from March 1993 to April 1996 there are 14 overestimations and 17 underestimations and one mean surveyed interest rate which is exactly equal to the actual future interest rate. Figure 3b displays the corresponding results for the six-month rate six months ahead. In this far distant horizon the number of over- and underestimations are the same - or 17 (17), out of 34, overestimations (underestimations). Thus, the two cases are very identical.

Table 2 shows that the mean surveyed interest rates, on average, have very slightly underestimated the actual interest rates at both horizons[12]. The standard deviations of the mean surveyed interest rates are however greater than the standard deviations of the actual interest rates. The correlations between the actual and expected six-month rates three- and six months ahead are 0.51 and 0.39, respectively. Not surprisingly, the correlation is greater for the shorter horizon.

Table 3 shows the forecast errors of the mean surveyed data set. We see that both the root mean square error (RMSE) and the mean absolute error (MAE) show about twice as great values for the six months ahead rate compared to the three months ahead rate. The mean absolute forecast error three (six) months ahead is about 0.5 (1.0) percent. In addition to the results displayed in Table 3 we found that the mean surveyed forecast errors are not significantly different from zero both for interest rates three- and six months ahead.
One way to assess the accuracy is to compare with forecasts made with other methods. We compare the survey forecast errors with forecast errors of the implicit forward rate and the martingale method. This later method predicts that today's spot rate will remain unchanged. The

[12] Notice that the surveyed interest rates comprise 32 (34) observations for the six-month rate three (six) months ahead while the actual interest rate comprises 38 observations. Therefore, we show the actual six-month rate three-and six months ahead which exactly correspond to the survey interest rates with 32 and 34 observations, respectively. For missing observations in the survey data set see Table 1.

three metods' forecast errors are displayed in Table 3. Notice that the surveyed interest rate comprises 32 (34) observations for the three (six) months ahead rates. Therefore, we show the forward rates- and the martingale forecast errors which exactly correspond to the survey interest rates. Out of the three methods the survey- and forward rates are about identical for forecasting future interest rates for both horizons measured both as RMSE and MAE. The martingale method is slightly worse for forecasting future interest rates. The results should be interpreted with caution because of the small number of observations.

Now we are going to compare our results with the corresponding data from USA. Since September 1969, the Goldsmith-Nagan Letter has conducted a quarterly survey of the interest expectations of a selected panel of approximately fifty of its subscribers who are known to the publisher to be market professionals. The panel members typically represent a variety of different kinds of financial institutions. In one issue per quarter the Goldsmith-Nagan Letter reports to its subscribers the results of the survey in the form of the median of the individual responses. Ferderer and Shadbegian (1993) used the consensus (median) interest rate forecast from the Goldsmith-Nagan Letter to forecast the three- and six months ahead U.S. three-month Treasury bill rate during 1969:3 to 1990:2. The survey forecast errors are compared to the forward rate forecast errors in Table 4. All means are insignificantly different from zero. Both average- and mean absolute errors indicate that the forward rates forecasts are more accurate for the three months forecast horizon while the survey forecasts are slightly more accurate for the six months forecast horizon.

Tables 3 and 4 indicate that the forecast errors in Ferderer and Shadbegian's study[13] are greater, both for survey- and forward rates, compared to the forecast errors in this study. The two studies both show mean survey forecast errors that are not significantly different from zero.

Prell (1973) studied the Goldsmith-Nagan median surveyed interest rates for the three-month Eurodollar rate and the three-month Treasury bill rate three- and six months ahead during September 1969-December 1972. The two maturities and horizons underestimated the actual interest rate. The underestimation was larger for the six month forecast horizon. He finds that the surveyed forecast errors for the two interest rates and horizons, measured as average absolute error, are smaller than the average absolute errors in Ferderer and Shadbegian's study but larger than in this study.

Prell's results show that the mean survey forecast errors for the two interest rates and horizons are smaller than the forecast method that predicts that today's spot rate will remain unchanged. This is in line with the results in this study as indicated in Table 3[14]. There was no significant tendency toward under- or overestimation of levels.

2.2 Do the survey forecast errors behave rational?

Figures 4a,b show the forecast errors at both horizons; i.e. the differential between actual and forecast in Figures 2a,b. It is not surprising that the six-month forecasts show greater errors than the

[13] Note that the maturity of the interest rates compared differs in the two studies. This study uses the six-month rate while Ferderer and Shadbegian use the three-month rate.

[14] Note that even in this case the two compared maturities differ in the two studies. Prell (1973) uses the three-month rate while this study uses the six-month rate.

three-month forecasts. The survey forecasts are rational if they use all available information. This implies that there is no autocorrelation in the forecast errors. A quick glance at Figures 4a,b shows that the forecast errors reveal clear signs of autocorrelation. This means that there is information which is not made use of. The autocorrelation coefficients are displayed in Table 5. Since the time series of the surveyed interest rates contain missing observations we split the series into subseries. For the three (six)-month horizon we look at two (three) subseries, December 1992-June 1994 and August 1994-June 1995 (December 1992-June 1994, August 1994-March 1995, and July 1995-January 1996). First, we test whether a particular value of the autocorrelation is equal to zero[15]. For the three (six)-month horizon, lags one and two (one, two and three) show autocorrelation during the period December 1992-June 1994. In this case we reject that the true autocorrelation coefficients are zero. We also test the joint hypothesis that all autocorrelations are zero by using the Q-statistic introduced by Box and Pierce[16]. We reject that the true autocorrelation forecast errors are all zero both for the three- and six-month horizons during December 1992-June 1994. To summarise, the survey forecasts behave rationally neither for the three-month horizon nor the six-month horizon.

Let us now ask to what extent the mean survey interest rate predicts the actual future interest rate. This could be done using the following regression model.

(1) $$r_{t+k} = \alpha_1 + \beta_1 E_t(r_{t+k}) + e_{t+k}$$

where $E_t(r_{t+k})$ is the mean surveyed expected interest rate at time t k periods ahead, and $e_{t+k} = r_{t+k} - E_t(r_{t+k})$ under the null hypothesis $\alpha_1=0$ and $\beta_1=1$, i.e. the residual term reflects purely random "news".

Note that equation (1) concerns the relation between the levels of the expected rate and the actual future spot rate. This version of the regression gives consistent estimation if the time series are stationary. The interest rates used in this study appear to be non-stationary according to Table 6. To give regression (1) stationarity we rewrite it as

(2) $$r_{t+k} - r_t = \alpha_2 + \beta_2 [E_t(r_{t+k}) - r_t] + e'_{t+k},$$

The subsequent change in the spot rate is regressed on the expected change over the previous period, $E_t(r_{t+k}) - r_t$. This is a test of the unbiasedness of the survey data. The results from fitting equation (2) to our data are displayed in Table 7. The β-coefficients are both less than one but not significantly, confirming the impression given by Figures 3a,b. The constant terms are both small and not significantly different from zero. The chi-square tests show that we cannot reject the joint hypothesis that $\alpha_2=0$ and $\beta_2=1$, for the six-month rate neither three- nor six months ahead.

[15] To test whether a particular value of the autocorrelation is equal to zero we use Barlett's test.

[16] They show that the statistic $Q=N\sum_{k=1}^{K}\hat{p}_k^2$ is (approximately) distributed as chi square with K degrees of freedom (K is the number of lags and $\hat{p}$ the autocorrelation coefficient)

Swedish results stand in contrast to two foreign studies, namely Kim (1996) and Friedman (1980). Kim (1996) examined the properties of survey based expectations[17] of the 90-day bank accepted bill rate and the 10-year government bond rate, respectively, in the Australian financial markets. The studied period covers the time from August 1985 to January 1993. One aim of the paper was to test the unbiasedness of the surveyed interest rates. Using equation (2)[18] he finds that the unbiasedness of the surveyed forecasts are rejected both for the 90-day bill rate and the 10-year government bond rate two- and four weeks ahead[19]. The β:s are 0.426 (-0.025) and 0.507 (0.089) for the 90-day bill (10-year government bond) rate two- and four weeks ahead, respectively.

Friedman (1980) used Goldsmith-Nagan survey data to test, among other things, the unbiasedness of surveyed answers - H_0: $(\alpha, \beta) = (0, 1)$[20]. The analyses focused on six interest rates, included in the survey, which are all yields on assets actively traded in the financial markets. The six interest rates are: The federal funds, three-month U.S. Treasury bills, six-month Eurodollar certificates of deposit, twelve-month U.S. Treasury bills, new issues of high-grade municipal bonds, long-term unity bonds, and seasonal issues of high-grade long-term. The sample period consists of thirty quarterly observations, beginning with predictions made in September 1969. The horizons are three and six months. The tests show that the survey respondents did not make unbiased predictions[21]. The general tendency is that $\alpha>0$ and $\beta<1$.

2.3 The diversity in the surveyed answers

In theoretical and empirical studies of the term structure of interest rates, as a rule, it is assumed that the studied group has identical interest rate expectations. In our survey data set we see that the respondents do not have identical interest rate expectations. In Figures 5a,b[22] we see the actual, maximum and minimum surveyed interest rates of the six-month rate three-and six months ahead, respectively, and in Figures 6a,b[23] the difference between the maximum and minimum values are

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[17] The surveyed answers were collected from various issues of the Australian Financial Review. The market expectations of future values of these interest rates were surveyed by Money Market Services Australia (MMS). They carry out weekly telephone surveys on one- and four weeks ahead point forecasts of the 90-day bill rate and the 10-year government bond rate. They survey the forecast of 20 to 25 financial market economists and market participants and report the median of the survey.

[18] Kim (1996) distinguishes between the unbiased expectations hypothesis, UEA, - tested according to equation (2) - and the weak rational expectations hypothesis, WREH, in the sense forecasters use all available information when forming expectations. He also tests the WREH and finds the surveyed forecasts to be weakly rational.

[19] Kim (1996) also examined the unbiasedness of surveyed USD/$A exchange rate one- and four weeks ahead. Even in the exchange rate market he finds the surveys to be not unbiased predictors of future exchange rates. The same results are shown in Chinn and Frankel (1991) data on monthly survey expectations of future USD exchange rates against 25 currencies for the period February 1988 to February 1991. They conclude that the expectations appear to be biased. MacDonald (1992) finds the same results of British survey-based monthly forecasts conducted on companies of G7 countries for the three months ahead USD exchange rates against the British Pound, the Yen and the Deutsche Mark for the period October 1989 to March 1991.

[20] Friedman (1980) used equation (1). He refers to Muth (1961) and says that "a key property of rational interest rate expectations is that they are unbiased" (p 456).

[21] Friedman stresses that the evidence of serial correlation invalidates the F tests. He presents results from testing the null hypothsis of unbiasedness by applying Zeller's (1962) "seemingly unrelated" regression procedure. The test statistic λ warrants rejecting the joint hypothesis of unbiasedness across all the "seemingly unrelated" regressions at 90 precent confidence interval for the three months ahead predictions and at 99 percent confidence interval for the six months ahead predictions.

[22] These figures should be interpreted in the same way as Figures 2a,b.

[23] These figures should also be interpreted in the same way as Figures 2a,b.

displayed. The mean difference between the maximum and the minimum value for the whole sample period is 0.0070 and 0.0121 for three- and six-month horizons, respectively. The spread is greater for the six-month horizon compared to the three-month horizon. This is natural since the uncertainty is greater for the longer horizon.

The maximum and minimum values comprises 30 and 32 observations for the three- and six month horizons, respectively. The actual interest rates fall within (outside) the range given by the survey maximum and minimum values, 15 (15) times at the three-month horizon and the six-month horizon 13 (19) times. Despite the fact that the spread is nearly twice as large for the longer horizon, there is a somewhat lesser share of actual observations that fall within the range given by the survey maximum and minimum values.

We may regard the difference between the maximum and minimum value for each survey day as a measure of the uncertainty referring to the interest rate development. The degree of uncertainty should be reflected as risk premia, rp_t^k. The risk premium is defined by the differential between the implicit forward rate, f_t^k, and the expected spot rate, $E_t(r_{t+k})$, or formally

(3) $$rp_t^k = f_t^k - E_t(r_{t+k})$$

We test this hypothesis by running the following regression

(4) $$rp_t^k = \alpha_3 + \beta_3[\max E_t(r_{t+k}) - \min E_t(r_{t+k})] + \in_t'$$

where max (min) $E_t(r_{t+k})$ is the maximum (minimum) surveyed interest rate. The regression results are displayed in Table 8. The $\overline{R}^2$ - values are extremely low, -0.0142 and 0.0034 for the three- and six-month horizons, respectively. β_3 has a positive sign as hypothesized, but neither the constant term- nor the β_3-coefficients are significantly different from zero on the 95 percent level.

III THEORY - THE EXPECTATIONS HYPOTHESIS

In the next section we will test the EH without a direct measure of expectations. Before doing that we need to distinguish between different forms of the EH. A standard formulation of the EH uses the implicit forward rate[24]. This can be decomposed into two parts, a forecast of the future interest rate and a term that may be labelled a risk premium, or

(5) $$f_t^k = E_t(r_{t+k}) + rp_t^k$$

where f_t^k is the implicit forward rate at time t for a six months investment that starts at time k, $E_t(r_{t+k})$ is the expected spot rate and rp_t^k the risk premium which is some form of compensation for bearing risk.

[24] How the forward rate is calculated is shown in the Appendix.

The most popular simple theory of the term structure is known as the pure expectations hypothesis (PEH). This requires that the expected risk premium is zero for all maturities, rp_t^k =0, or formally

(6) $$E_t(r_{t+k}) = f_t^k$$

The PEH should be distinguished from the expectations hypothesis, EH, which says that the expected risk premium, rp_t^k, is constant over time and the same for all maturities. We talk about the liquidity preference hypothesis (LPH) when the risk premium depends on the term to maturity of the bond and $rp_t^{k,6m} > rp_t^{k,6m-1}$ [25].... etc. Note that rp_t^k has a subscript t because it may vary over time. In this case we talk about a time-varying risk premium.

When the theory is tested without a direct measure of expectations we need an assumption about expectations. A popular assumtion is rational expectations, RE, or

(7) $$E_t(r_{t+k}) - r_{t+k} = v_{t+k}$$

where v_{t+k} is a serially uncorrelated forecast error. Hence, a test of the PEH+RE implies that the expected excess return should have a zero mean, the forecasts be made utilizing all available and relevant information at the time of making the forecast, and should be serially uncorrelated. The EH+RE yields similar predictions as the PEH+RE. The excess yield is now equal to the constant risk premium under EH+RE and equal to an increasing risk premium for each bond to maturity, under the LPH+RE.

Apart from the constant risk premium, the main testable implications using regression analysis of the PEH, EH and LPH are identical. Equation (7) suggests a straightforward regression-based test on:

(8) $$r_{t+k} = \alpha_4 + \beta_4 f_t^k + \varepsilon_{t+k}$$

where $\varepsilon_{t+k} = r_{t+k} - E_t(r_{t+k})$ under the null hypothesis $\alpha_4 = 0$ and $\beta_4 = 1$, i.e. the residual term reflects purely random "news". For the PEH we have a zero constant term and for the EH $\alpha_4 \neq 0$. LPH suggests increasing α when increasing the time to maturity. Under PEH, EH and LPH we expect $\beta_4 = 1$. Since $E_t(r_{t+k})$ is (under RE) independent of information at time t, the OLS yields unbiased estimates of the parameter. Note, however, that if the risk premium is time-varying and correlated with the expected future interest rate the parameter estimates in equation (8) will be biased.

To adopt the terminology in this study with the terminology in the term structure literature we simply talk about the EH no matter we mean the PEH or the EH.

The most common used test, in the literature, of the EH is a joint hypothesis which implies that $\alpha = 0$, and $\beta = 1$ and the assumption of rational expectations, EH+RE. With direct measured expectations it is, however, possible to isolate tests of the EH without assuming rational expectations. This is what we are going to do in section V.

[25] 6m is the lenght of the investment - six months.

In this section we have distingushed between different forms of the EH. In the next section we perform the test of the EH+RE without a direct measure of expectations.

IV TESTS OF THE EXPECTATIONS HYPOTHESIS WITHOUT A DIRECT MEASURE OF EXPECTATIONS

When we use data without a direct measure of expectations a joint test of the EH and rational expectations (EH and RE) is used. To show this the starting point is equation (8). However, this concerns the relation between the levels of the forward rate and the future spot rate. This is a version of the test of the EH+RE that is not commonly used in the literature (see Shiller 1990). The reason is that the interest rates might show signs of mean non-stationarity. To achieve stationarity we rewrite it, following Shiller (1990), Fama (1984) and others, as

$$(9) \qquad r_{t+k} - r_t = \alpha_5 + \beta_5(f_t^k - r_t) + \varepsilon'_{t+k'} ;$$

The change in the spot rate is regressed on the forward premium in the previous period, fp_t^k, defined by

$$(10) \qquad fp_t^k = f_t^k - r_t$$

The interest rate differentials in equation (9) are stationary. It is therefore legitimate to estimate this equation using OLS. In the literature it is the most frequently used model (see Shiller 1990). It is used by Froot (1989), Hörngren (1986) and Dahlquist and Jonsson (1994). With this model it is possible to make comparisons with other studies.

The null hypothesis of the expectations theory postulates that the intercept term is equal to zero (α_5 =0) and the coefficient of the forward premium is equal to one (β_5=1) in equation (9). Note that this is a joint test. It tests that there is no risk premium implying that the forward premium is equal to the expected future interest rate change, conditional on the maintained assumption that the market's expectations are made rationally, meaning that the expectation is an efficient forecast of the future interest rate change and the residual, $\varepsilon'_{t+k'}$, is purely random. If the two assumptions hold, the forward premium is an unbiased predictor of the future interest rate change. If the coefficient of the forward premium is significantly different from one it depends either on an expectation error or a premium that is correlated with the level of the interest rate. If the constant term is different from zero it depends, in the same way, either on a systematic error or a constant risk premium or both.

In addition to the standard regression there are other approches to test the EH. Ekdahl and Warne (1990) used an vector autoregressive (VAR) model and Hördahl (1994) used an autoregressive conditional heteroscedasticity in mean (ARCH-M) model to test the EH on Swedish data.

We present the results from fitting equation (9) to data from the Swedish T-bill market in Table 9. The coefficients of the forward premia are both less than one but not significant. The coefficient of the forward premium decreases with the horizon. It is easier to forecast interest rates in the near future than into the more distant future. The constant terms are both less than zero but not significant.

Further, we cannot reject the joint hypothesis that $\alpha_5=0$ and $\beta_5=1$. This means that the EH+RE cannot be rejected for either of the two horizons.

1 Foreign studies of the EH

The numbers of foreign studies of the EH are enormous. Only a small number of these tests, which start with Macauley (1938) have found support for the EH. A still smaller number statistically reject the alternative hypothesis that the spreads between long- and short interest rates have no forecast power at all for future interest rates' changes. The null hypothesis in these tests is the joint hypothesis that all variances in the spread between short and long rates depend on future interest rate changes and that expectations are rational. Without further information it is apparently not possible to draw any conclusions as to which category the rejection of the EH+RE should be classified. Gerlach and Smets (1995)[26] used three-, six- and twelve months Euro-rates to test the EH+RE for a sample of 17 countries. They found that all β-coefficiants were positive and significantly different from zero (Sweden showed the greatest β-values[27]). In 35 out of 51 cases they cannot reject $\beta=1$. Furthermore, in 26 out of 51 cases they cannot reject the joint hypothesis that $\alpha=0$ and $\beta=1$. In Table10 a compilation of some foreign estimations of the EH+RE where only the short interest rates are displayed. The models used are in general regression (9), or some variant of it. The slope coefficients are far below one. Certain studies on U.S. data even show a slope coefficient not significantly different from zero. The results in Table 10 look specially bad for the EH+RE. However, Hsu and Kugler (1997)[28] detect that the predictive power of the spread for short interest rate changes has improved when they find support for the EH+RE for the most recent of four subperiods studied, 1987-85. For the subperiods 1973-79, 1979-82 and 1982-87 and the whole sample period, 1973-95, they do not find support for the EH+RE.

Table 11 displays some results from tests of the EH+RE using long interest rates. Bekaert, Hodrick and Marshall (1997) reject the EH+RE on U.S. data both for three- and five years interest rates. Froot (1989) tests the one (thirty) year (s) rate six months ahead and finds no support for the EH+RE. In line with Bekaert, Hodrick and Marshall (1997) one of Froot's regressions gives negative slope coefficient. The results look bad for the EH+RE, on U.S. data, which correspond well with Shiller (1990) when the forecast horizon is small and the maturity of the forward rate is long (not shown in the table). Testing the EH+RE for long interest rates on European data paint a different picture. Engsted (1996) finds support for the EH+RE on Danish data. Hardouvelis cannot reject the EH+RE for the ten-year rate neither for France nor Italy.[29]

The predominant approach that the variance in the forward premia reflects risk has already been shown for other markets. Hodrich and Srivastava (1984,1986) have shown that forward- and future

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[26] They used the following model to test the EH+RE: $(r_{t+j-1} + r_{t+j-2} + ... + r_t)$/j - $r_t = \alpha + \beta(R_t^j - r_t) + v_t$ where R_t^j is the j-period investment rate at time t and r_t is the 1-period interest rate at time t. The theory implies that the realised future return on rolling over an 1-month investment over j periods should equal the current spread between a j-period- and an 1-period interest rate.

[27] The β-coefficients, not significantly different from one, are 1.24, 1.19 and 1.13 for the three-, six- and twelve month rates, respectively.

[28] They used McCallum's model.

[29] However, tested on U.S. data the EH+RE is rejected.

rates in the exchange rate markets are an unbiased predictor of future spot rate exchange rates. Their interpretation is that the variance in the exchange risk premium is higher than the variance in expected depreciation. The result is confirmed by Nessén (1994) in a study of Sweden's, Norway's, Denmark's and Finland's exchange rates markets that the term-premium in the preceding period is an unbiased predictor of the future exchange rate. Her study also shows that the variance of the risk premium is higher than the variance of the expected exchange rate changes for all countries.

2 Swedish studies of the EH

In this study, equation (9) is chosen to test the EH+RE. The reason is that Froot (1989), Hörngren (1986) and Dahlquist and Jonsson (1994) have used this expression to estimate the spot rate differential. Hörngren's study is similar to Fama's (1984) pioneer paper but contrary to the latter, Hörngren studies the capability of forward rates to forecast future interest rates with different maturities while Fama studies the forecast power several periods in the future. Hörngren's study comprises the period 1980-1985 i.e. when Swedish banks had the right to borrow a sum of 25 per cent of their equity at the discount rate and at the penalty rate unlimited borrowing was permitted. Banks could also deposit excess reserves i.e. have negative borrowing, and on those deposits they earned a fixed interest rate. Needless to say, this was lower than the discount rate and the penalty rate.

The results from Hörngren's study are shown in Table 12. He uses the forward premia one-month rate one month ahead (1m1m), one-month rate two months ahead (1m2m) and three-month rate three months ahead (3m3m). Hörngren finds that the slope coefficients for the forward premia one-month rate one month ahead (1m1m) and one-month rate two months ahead (1m2m) are less than one. These are significantly different from zero on the 16- and 10 percent levels, respectively, which suggest some evidence that the forward-spot rate differentials contain information about future premia. The three-month rate three months ahead (3m3m) displays the inverted result. The slope coefficient is greater than one but not significantly. In this case the forward-spot rate differential contains un unbiased predictor of the future change in the three month rate.
Hörngren's results are in contrast to the results in this study which cannot reject the EH+RE. The different results may depend on the fact that Hörngren used interest rates on bank certificates of deposits with possible default premiums. Further, the capital market in the early eighties was undeveloped and highly regulated.

Dahlquist and Jonsson (1994) use T-bills and their study also covers the time when Sweden applied a fixed exchange rate regime or specifically, January 1984 to July 1992. They also use equation (9) to estimate the spot rate differential. Their study contains the forward one-month rate one month ahead (1m1m), the one-month rate two months ahead (1m2m), the three-month rate three months ahead (3m3m), and the six-month rate six months ahead (6m6m). The results are displayed in Table 12. The slope coefficients are all not significantly different from one, which is good for the EH. The conclusion is that the EH+RE cannot be rejected.
Dalquist and Jonsson's results correspond well to the results in this study. The EH+RE cannot be rejected in the two studies. In the Swedish money market the EH+RE seems to be valid both under fixed- and flexible exchange rate regimes.

Ekdahl and Warne (1990) use a VAR-model[30] to study the Swedish term structure of interest rates during 1984-1989. They used data for the one month interest rate of T-bills and five year government bonds. The results show that the forecast power - in general - decreases with the horizon for the shortest interest rates but increases with the horizon for forecasts several years into the future. As in this study the EH+RE cannot be rejected.

Hördahl (1994) uses an ARCH-M ("autoregressive conditional heteroscedasticity in mean") model[31] to study the term structure of interest rates for four interest rates series - 2 vs 1 month, 4 vs 2 months, 6 vs 3 months and 10 years vs 1 month - of T-bills respectively bonds. The results show that there is no support for a variance-dependent risk premium. However, the author found a weak support for a general time-varying risk premium. The conclusion is that the EH cannot be rejected with the exception of 4 vs 2 months' T-bills. Hence, in general, the results coincide with the results of this and Dahlquist and Jonsson's study.

In the next section we follow the discussion how to derive the decomposition of the forward premium.

V TESTING THE EXPECTATIONS HYPOTHESIS WITH SURVEY DATA

1 Decomposition of the forward premium

[30] A vector autoregressive model, or VAR for short, is a time-series model used to forecast values of two or more economic variables. Suppose $y_{1t} \dots y_{nt}$ are economic variables whose values we wish to forecast. A VAR model for these variables is given by the following n-equation model, with the number of lags equal to k periods.

$Z_t = \sum_{i=1}^{k} A_i Z_{t-i} + e_t$. All variables are treated as endogenous. Notice that no current values for any variables appear on the right hand side of any equation. Suppose we wish to use the VAR model for forecasting, say y_{1t+1}. We use the first equation in the model.

$$\hat{y}_{1t+1} = \hat{a}_{11}\, y_{1t} + \dots + \hat{a}_{1n}\, y_{nt} + \hat{b}_{11}\, y_{1t-1} + \dots + \hat{b}_{1n}\, y_{nt-1} + \hat{k}_{11}\, y_{1t-(k-1)} + \dots + \hat{k}_{1n}\, y_{nt-(k-1)}$$

where $\hat{y}_{1t+1}$ is the forecast and the $\hat{a}$:s, $\hat{b}$:s and $\hat{k}$:s are estimated coefficients.

[31] The ARCH-M model used is: $y_t = \beta x_t + \delta h_t + u_t$, $V[u_t | A_{t-1}] = h_t^2$ and $h_t^2 = \gamma + \alpha \sum_{i=1}^{q} w_i\, u_{t-i}^2$. y_t is the ex-post excess holding yield over a long term T-bill with L days to maturity over a short term T-bill with S days to maturity, where L=2S. It is defined as $y_t = \frac{(1+r_t^L)^2}{(1+r_{t+1}^S)}$ - (1+r_t^s). x_t is a vector of explanatory variables and A_{t-1} is all available information at time t-1. h_t^2 is the conditional variance as a function of past squared errors, u_{t-i}^2. The parameters of the ARCH-M model are estimated with a number of different lags in the weighted average of squared residuals. The most common method utilized is the maximum likelihood method. The log likelihood function may be expressed as $\ln L(f) = \sum_{t=1}^{T} \ln L_t(f)$ where $\ln L_t(f) = -\ln(h_t) - \frac{u_t^2}{2h_t^2}$. The expression is maximized with respect to φ. If one or more of the independent variables in the first equation are significant the excess holding yield is not constant. Such a time-varying risk premium makes the EH to be rejected.

In line with other Swedish tests of the EH+RE our results reported in Table 9 show that we cannot reject it. One interpretation is that forward rates reflect expected future interest rates and that expectations are rational. However, in light of the rejection of the EH+RE in a large number of U.S. studies an alternative interpretation is that neither of these condition holds. For Sweden we have already given an indication of that neither RE nor EH holds. This is what we are going to test in this section. Using the survey data it is possible to decompose the forward premium into an expectational component and a risk premium. By definition, the risk premium, rp_t^k, is

(11) $$f_t^k - r_t = E_t(r_{t+k} - r_t) + rp_t^k$$

or

(12) $$fp_t^k = E_t(\Delta_{t,k} r) + rp_t^k$$

where fp_t^k and $E_t(\Delta_{t,k} r)$ are both observable. The variance of fp_t^k is

$$\text{Var}(fp_t^k) = \text{Var}(E_t(\Delta_{t,k} r)) + \text{Var}(rp_t^k) + 2\text{Cov}(E_t(\Delta_{t,k} r), rp_t^k)$$

The time series for the risk premia, rp_t^k, are shown in Figures 7a,b together with the expected interest rate differentials, $E_t(\Delta_{t,k} r)$ and the forward premia, fp_t^k. The variance of the $E_t(\Delta_{t,k} r)$ is smaller (about the same) than (as) the variance of the fp_t^k for the three (six) months ahead rate. The variances in the fp_t^k:s are about twice as great as the variances in the rp_t^k:s. The mean of the rp_t^k:s are both greater than zero. The variances of the rp_t^k for the three months ahead rate is smaller than the variance of the $E_t(\Delta_{t,k} r)$. They show negative correlation. This is confirmed in Table 13 and 14 which contain the variances and correlations of the time series. For the six months ahead rate the variance of the rp_t^k is about half the size of the variance in the $E_t(\Delta_{t,k} r)$ and they show positive correlation. A great variance in rp_t^k indicates that the EH does not hold. Equation (12) reveals that if the variance in the rp_t^k is smaller (greater) than the variance in the fp_t^k the covariance between rp_t^k and $E_t(\Delta_{t,k} r)$ must be positive (negative) (otherwise the variance in fp_t^k cannot be high). This is confirmed in Tables 13 and 14. The variances in the fp_t^k:s are smaller than the variances in the acutal interest rate differentials, $\Delta_{t,k} r$. This means that the fp_t^k:s do not keep up with the $\Delta_{t,k} r$:s.
By definition the expectation error, u_t^k, is

(13) $$u_t^k = \Delta_{t,k} r - E_t(\Delta_{t,k} r)$$

The variances in the u_t^k:s are nearly twice as great as the variances in the fp_t^k:s and there is positive correlation between the variables. This indicates that RE does not hold. Figures 7a,b show time-varying risk premia while Figures 8a,b display expectation errors.

To summarize, the above analysis of the variances of rp_t^k and u_t^k suggests that neither RE nor EH hold. However, according to Table 9 the EH+RE cannot be rejected. To investigate this we turn to decompose the β-coefficient into two components one measuring the forecast error and one the risk premium.

2 Decomposition of the b -coefficient[32]

Given that we may decompose fp_t^k we can also decompose the regression coefficient. The least-squares estimator $\hat{b}_5$ of equation (9) is

$$(14) \qquad \hat{b}_5 = \frac{Cov(r_{t+k} - r_t,\ fp_t^k)}{Var(\ fp_t^k)} = \frac{Cov(\Delta_{t,k} r,\ fp_t^k)}{Var(\ fp_t^k)}$$

The actual, ex post, change in the interest rate is equal to the expected change plus an expectation error, i.e.

$$(15) \qquad \Delta_{t,k} r = E_t(\Delta_{t,k} r) + u_t^k$$

$E_t(\Delta_{t,k} r)$ denotes expected change in the spot rate. Substituting $\Delta_{t,k} r$ in equation (14) with the expression in equation (15), we get (16)

$$(16) \qquad \hat{b}_5 = \frac{Cov(E_t(\Delta_{t,k} r) + u_t^k,\ fp_t^k)}{Var(\ fp_t^k)}$$

or

$$(17) \qquad \hat{b}_5 = \frac{Cov(E_t(\Delta_{t,k} r),\ fp_t^k) + Cov(u_t^k,\ fp_t^k)}{Var(\ fp_t^k)}$$

The assumption of rational expectations requires that $Cov(u_t^k,\ fp_t^k)$ in equation (17) is equal to zero. Standard tests of the EH+RE demand this condition to be fulfilled but with data on $E_t(\Delta_{t,k} r)$ it may be relaxed. To see this we substitute equation (12) into (17). Straightforward exercise in least-squares algebra breaks down the $\hat{b}_5$-coefficient into one component attributable to an expectation error, b_{ee}, and one component attributable to a time-varying risk premium, b_{rp}.

$$(18) \qquad \hat{b}_5 = \frac{Cov(\ fp_t^k - rp_t^k,\ fp_t^k) + Cov(u_t^k,\ fp_t^k)}{Var(\ fp_t^k)} =$$

$$\frac{Var(\ fp_t^k)}{Var(\ fp_t^k)} - \frac{Cov(rp_t^k,\ fp_t^k)}{Var(\ fp_t^k)} - \frac{Cov(u_t^k,\ fp_t^k)}{Var(\ fp_t^k)} \equiv 1 - b_{rp} - b_{ee}$$

If b_{ee} is significantly different from zero the forward premium contains an expectation error. No systematic expectation errors are fulfilled if b_{ee} is zero. Departure from zero of the b_{rp}-component indicates a time-varying risk premium making the EH to be rejected. b_{rp} is zero if the variance of the risk premium is zero. In this case the EH holds.

[32] The decomposition was suggested by Froot (1989) and has been applied in the exchange-rate market by Nessén (1994).

We now turn to the empirical results of the decomposition of the β into an expectation error, b_{ee}, and a risk premium, b_{rp}, according to equation (18).

The results are displayed in Table 15. b_{ee} is negative for both maturities and b_{rp} is positive for both maturities. The b_{rp}:s show greater numerical values than the b_{ee}:s. It remains to test if the expectation errors and the risk premia are significantly different from zero i.e., create confidence intervals for the point estimates in Table 15. If this is the case the positive risk premia can be offset by the negative expectation errors making the EH+RE not to be rejected. This is what we are now going to test.

We can test the hypothesis that b_{rp}=0, directly, by running the regression

(19) $$rp_t^k = \alpha_6 + \beta_6 \, fp_t^k + e_t^{'}$$

where

(20) $$\hat{b}_6 = \frac{Cov(rp_t^k, fp_t^k)}{Var(fp_t^k)} = b_{rp}$$

A zero risk premium is tested by the hypothesis that α_6=0[33]. We do the corresponding test for b_{ee}=0 with the regression

(21) $$u_t^k = \alpha_8 + \beta_8 \, fp_t^k + e_t^{'''}$$

where $$\hat{b}_8 = \frac{Cov(u_t^k, fp_t^k)}{Var(fp_t^k)} = b_{ee}$$

If β_8=0 cannot be rejected it means that b_{ee} is not significantly different from zero.

Table 16 displays the results from running equations (19), and (21). Regression (19) shows the time-varying risk premia. Further, the rp_t^k:s vary significantly with the fp_t^k:s and increase with the horizon. They are 0.27 and 0.33 for the three- and six months ahead rates, respectively. This means that the b_{rp} component is significantly different from zero. The constant parts are 0.0020 and 0.0048 for the three- and six months ahead rates, respectively. So, we have both a constant- and a time-varying risk premium. Regression (21) shows that $\hat{b}_8$ is not significantly different from zero. This means that b_{ee} - the expectational component - is not significantly different from zero.[34]

[33] We can also test whether b_{rp} is different from zero, indirectly, by running the regression

$$E_t(\Delta_{t,k} r) = \alpha_7 + \beta_7 \, fp_t^k + e''_{t}$$

where

$$\hat{b}_7 = \frac{Cov((\Delta_{t,k} r), fp_t^k)}{Var(fp_t^k)} = \frac{Cov(fp_t^k - rp_t^k, fp_t^k)}{Var(fp_t^k)} =$$

$$1 - \frac{Var(rp_t^k, fp_t^k)}{Var(fp_t^k)} = 1 - b_{rp}$$

In the regression we can test the hypothesis that $\hat{b}_7$=1. This is equivalent to testing if b_{rp}=0. A zero risk premium is tested by the hypothesis that $\hat{a}_7$=0. Of course, the two regressions will give the same results.

[34] Assume that $b_{ee} \neq 0$ in a particular sample. Even in this case the expectations may still be rational. Long sample periods include occurences that appear with long intervals. In short sample periods - as in this study - these

To summarize, the results from Table 9 show that the joint test of the EH+RE cannot be rejected. However, according to Tables 15 and 16, there is a constant- and a time-varying risk premium that are significantly different from zero making the PEH and EH to be rejected. The expectational component, b_{ee}, is not significantly different from zero and shows opposite signs, compared to the time-varying risk premium. Now we have an explanation for the surprising result that so many tests of the EH+RE applied to U.S. data reject the EH+RE while applied to Swedish data do not reject it. The Swedish forward premium contains a time-varying risk premium which is significantly different from zero. However, this positive risk premium does not cause the joint test of the expectations hypothesis, EH+RE, to be rejected. The reason is a negative, but not significant, expectation error which is not great enough to make the sum of the expectation error and the time-varying risk premium too small not to reject the joint test of the EH+RE. The results should, however, be interpreted with caution. The number of observations are quite small.

3 Comparison with Froot's results and tests made by other authors

As in this study Froot (1989) uses equation (9) to test the EH+RE. The time is 1969-1986. In the short end of the term structure he tests the three-month T-bill- and Eurodollar rates three months ahead (3m3m). Both instruments reject the EH+RE on the 95 percent level. However, the Eurodollar rate does not reject the EH+RE on the 90 percent level.[35] Froot's components of failure of the EH+RE are found in Table 17. His results show that the time-varying risk premia are the most dominant explanation in the bias of the difference between the forward rate and today's spot rate predictions. The quantitative importance of the systematic errors for the differential between the forward premium appears greater for long term interest rates (not shown in the table). Both the time-varying risk premia, b_{rp}, and the expectation errors, b_{ee}, for the short terms are positive. In this study the time-varying risk premia are positive and the expectation errors are negative. In Froot's study the time-varying risk premia (expectation errors) are significantly (not significantly) different from zero. This rejects the EH. In this study the positive time-varying risk premia are significantly different from zero which reject the EH. The negative expectation errors are not significantly different from zero, but still great enough to offset the positive risk premia making the joint test of the EH+RE not to be rejected.

Batchelor (1990) used a different survey data set, namely Blue Chip Financial Forecasts. From October 1982 to March 1987 thirty to fifty forecasters were asked about the three month U.S. Treasury bill rate one month into the future (3m1m). He had assess to the panel's mean values. Bachelor used the standard regression, equation (9), and made the decomposition of the β-coefficiant into an expectation error and a risk premium. The results are displayed in Table 17. They are very similar to Froot's results. There is a positive and significant time-varying risk premium and a positive and not significant expectation error. This rejects the EH.

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occurences do not appear a typical number of times which implies that the forecasts are systematically mistaken. Froot calls these occurences "peso-problems". Therefore, rational expectations may include expectation errors.

[35] In a study with data from New Zealand Margaritis (1994) shows with help of an autoregressive conditional heteroscedasticity in mean model (ARCH-M) support for the EH in the short end of the term structure. Further, he shows there are signs of a time-varying risk premium for long term interest rates.

MacDonald and Macmillan (1994) used UK survey data called Consensus Forecasts. Since October 1989 about thirty forecasters have been asked abou t their expectations of the UK three-month interbank rate three months ahead (3m3m).[36] The sample period covers the time October 1989-October 1992. The results are displayed in Table 17. They are very similar to Froot's and Batchelor's results. They find a positive and significant time-varying risk premium and a not significant expectation error. The EH[37] is rejected.

VI SUMMARY AND CONCLUSIONS

The news agency Direkt's survey of expected interest rates is the first of this kind in Sweden. One purpose of this paper is to present and analyse the surveyed answers made by the news agency Direkt. We have presented the mean surveyed answers. From these we make quantitative analyses. The uncertainties and spread in the survey answers were discussed. We test the predictive power of the mean surveyed interest rates. The second half of the study tests statistically to what extent the forward interest rates that are implicit in the term structure can be used as a forecast of the future interets rates: i.e. it tests the expectations hypothesis, EH, of the term structure of interest rates. The coefficient of the forward rate can be decomposed into two components one measuring the risk premium and one the expectation error. With this decomposition we learn something about their realative importance.
Our major findings are summarised.

a) The mean surveyed answers have on average underestimated the actual future interest rate, both for the six-month rate three-and six months ahead. The respondents have overestimated the three-(six) month horizon 14 (17) out of 32 (34) observations.

b) The survey forecast errors are about twice as great for the six-month horizon compared to the forecast error for the three-month horizon measured both as average- and mean absolute errors. The mean surveyed forecast errors are compared to the forecast errors of the forward rates and the martingale method. The survey- and forward rates are about identical for forecasting future interest rates for both horizons. The martingale method measures the future interest rates with less accuracy.

c) The surveyed interest rates are unbiased predictors of actual future interest rates. This is confirmed when the surveyed interest rates are regressed on the future actual interest rates.

d) The actual interest rates fall within (outside) the range given by the survey maximum and minimum values 15 (15) times for the three-month horizon and 13 (19) times for the six-month horizon.

e) The spread between the maximum and minimum surveyed interest rates is regressed on the risk premium. Neither the constant terms- nor the β-coefficients are significantly different from zero.

f) This study does not reject the EH+RE for any of the two horizons. This is in contrast to most tests of the EH+RE applied to U.S. data, but in line with the results from other Swedish tests.

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[36] However, this is not a consistent sample. It has been modified into a consistent panel data set of twenty-five forecasters.
[37] MacDonald/Macmillan also used the standard regression, equation (9).

g) According to Froot (1989) the β-coefficient of the forward premium is decomposed into an expectation error and a risk premium. The Swedish money market contains a positive time-varying risk premium which is significantly different from zero. This rejects the EH. However, this risk premium is offset by a negative, not significant, expectation error making the EH+RE not to be rejected.

h) The presentation of the surveyed interest rates is built on a survey study during a relatively short time period. Therefore, it is not possible to say to what extent the results are of a more general validity.

FIGURES AND TABLES

Figure 1: The term structure of interest rates. Interest rates against time and time to maturity.

Table 1: Missing observations (NA) in the mean, maximum and minimum surveyed data for the six-month rate three-, t+3, and six months, t+6, ahead.

Time	Mean (t+3)	Max and min	Mean (t+6)	Max and min
1994 July	NA	NA	NA	NA
1995 April			NA	NA
1995 May			NA	NA
1995 June			NA	NA
1995 July	NA	NA		
1995 August	NA	NA		
1995 September	NA	NA		
1995 October	NA	NA		
1995 November	NA	NA		
1995 December		NA		NA
1996 January		NA		NA

Table 2: Mean and standard deviations of actual six-month rate and surveyed six-month rate three- and six months ahead. December 1992 to January 1996. The actual six-month rate three (six) months ahead with 32 (34) observations corresponds to the surveyed interest rates.

	Actual six-month rate(total sample at time t)	Actual six-month rate (6m3m)	Surveyed six-month rate three months ahead (6m3m)	Actual six-month rate (6m6m)	Surveyed six-month rate six months ahead (6m6m)
Mean	0.0809	0.0782	0.0770	0.0755	0.0743
Standard deviation	0.0089	0.0096	0.0111	0.0109	0.0116
Number of observations	38	32	32	34	34

Table 3: Survey- and implicit forward rates forecast errors and forecast errors for the martingale method which predicts that the spot interest rate will remain unchanged. Six-month rate three-and six months ahead, respectively. December 1992-January 1996.

	Survey 6m3m	Survey 6m6m	Forward 6m3m	Forward 6m6m	Martin gale 6m3m	Martin gale 6m6m
Mean	-0.0012	-0.0008	0.0006	0.0033	0.0016	0.0051
RMSE[38]	0.0068	0.0129	0.0060	0.0119	0.0077	0.0141

[38] The root mean square error (RMSE) is computed as RMSE = $\sqrt{\frac{1}{N}\sum(\hat{x}_i - x_i)^2}$ where $\hat{x}_i$ is the predicted value, x_i is the actual, and N is the number of periods.

MAE[39]	0.0047	0.0098	0.0048	0.0103	0.0057	0.0123
Number of observations	32	34	32	34	32	34

Table 4: Survey forecast errors for the Goldsmith-Nagan data for the three-month rate three- and six months ahead and the forecast errors for the forward rates during 1969:3-1990:2 according to Ferderer and Shadbegian (1993).

	3m3m		3m6m	
	Survey	Forward	Survey	Forward
Mean error	0.0006	0.00004	0.0004	0.0002
RMSE	0.0165	0.0154	0.0189	0.0190
MAE	0.0105	0.0100	0.0131	0.0134

Table 5: Autocorrelations in the survey forecast errors for the six month rate three-and six months ahead.

	6m3m			6m6m	
Lag	ρ_k	ρ_k	ρ_k	ρ_k	ρ_k
1	0.741	0.510	0.894	0.078	0.148
2	0.587	-0.026	0.755	0.013	
3	0.353		0.620		
4	0.347		0.434		
Time	92:12-94:6	94:8-95:6	92:12-94:6	94:8-95:3	95:7-96:1
Number of observations	19	11	19	8	7

Table 6: Dickey-Fuller (DF) unit root test. December 1992-January 1996. The Augmented Dickey-Fuller (ADF) test has one lagged dependent variable included in the estimated equation.
*, **, ***, significant at ten, five, and two percent levels, respectively.

Variable	DF	ADF
r_{t+3}	-0.7995	-0.9897
r_{t+6}	-0.3740	-0.7151
$r_{t+3} - r_t$	-3.7374***	
$r_{t+6} - r_t$	-3.3555**	

[39] Similarly, the mean absolute error (MAE) is defined as MAE = $\frac{1}{N}\sum\left|\hat{x}_i - x_i\right|$.

f_t^3	-1.1548	-3.8669***
f_t^6	-1.0475	-4.7989***
$f_t^3 - r_{t+3}$	-1.9015	-8.8576***
$f_t^6 - r_{t+6}$	-1.8066	-7.1571***
rp_t^3	-3.1181*	-2.0172
rp_t^6	-1.3669	-2.0895
$rp_t^3 - rp_t^{3-1}$	-8.0576***	
$rp_t^6 - rp_t^{6-1}$	-4.5378***	
$\max [E_t(r_{t+3})] - \min[E_t(r_{t+3})]$	-4.9139***	
$\max [E_t(r_{t+6})] - \min [E_t(r_{t+6})]$	-4.9507***	
$E_t(r_{t+3})$	-0.5615	-0.0735
$E_t(r_{t+6})$	-0.8224	-0.7164
$E_t(r_{t+3}) - r_t$	-5.7454***	
$E_t(r_{t+6}) - r_t$	-3.5928**	

Table 7: Regression results from estimating the expected mean interest rate on the actual interest rate according to equation (2), $r_{t+k} - r_t = \alpha_2 + \beta_2 [E_t(r_{t+k} - r_t)] + e'_{t+k'}$. Newey and West (1989) standard errors are given in parentheses. The standard errors are corrected for overlapping observations. December 1992-January 1996.

	Eq(2) 6m3m	Eq(2) 6m6m
α_2	0.0005	0.0001
Standard error	(0.0017)	(0.0053)
t: $\alpha_2 = 0$	(0.2596)	(0.0198)
β_2	0.7458	0.8148

Standard error	(0.2148)	(0.3377)
t: $\beta_2 = 0$	(3.4723)	(2.4131)
t: $\beta_2 = 1$	(1.1834)	(0.5484)
Chi-square test, $\alpha_2 = 0$, $\beta_2 = 1$	1.7537	0.3965
p-value	0.4161	0.8202
$\overline{R}^2$	0.2342	0.1222
DW	0.40	0.10
Q test	22.87	86.96
p-value	0.0065	0.0000
ARCH test	21.72	29.37
p-value	$3*10^{-6}$	$6*10^{-8}$
Kolmogorv-Smirnov test		
p-value	>0.15	0.054
Maximum gap[40]		
Number of observations	32	34

Table 8: Regression results from estimating the risk premium on the difference between the maximum and minimum surveyed interest rates according to equation (4), $rp_t^k = \alpha_3 + \beta_3[\max E_t(r_{t+k}) - \min E_t(r_{t+k})] + \in_t^{'}$. Newey and West (1989) standard errors are given in parentheses. The standard errors are corrected for overlapping observations.

	6m3m	6m6m
α_3	0.0004	0.0021
Standard error	(0.0016)	(0.0017)
t: $\alpha_3 = 0$	(0.2257)	(1.2472)

[40] Rejection limits are: 1 percent: 0.3327, 5 percent: 0.2776 and 10 percent: 0.2490.

β_3	0.1904	0.1999
Standard error	(0.2659)	(0.1320)
t: β_3=0	(0.7159)	(1.5137)
$\overline{R}^2$	-0.0142	0.0034
DW	0.7829	0.7344
Q test	24.90	31.06
p-value	0.0031	0.0003
White's test	1.4113	1.0338
p-value	0.4938	0.5964
Kolmogorov-Smirnov test p-value	0.045	0.059
Number of observations	30	32

Table 9: Results from estimating regression (9), $r_{t+k} - r_t = \alpha_5 + \beta_5(f_t^k - r_t) + \varepsilon'_{t+k}$. Newey and West (1989) standard errors are given in parentheses. The standard errors are corrected for overlapping observations.

	6m3m	6m6m
α_5	-0.0015	-0.0038
Standard error	(0.0016)	(0.0037)
t: α_5 = 0	(0.9304)	(1.0312)

β_5	0.9118	0.8663
Standard error	(0.2082)	(0.2173)
t: $\beta_5 = 0$	(4.3791)	(3.9871)
t: $\beta_5 = 1$	(0.4236)	(0.6153)
Chi-square test, $\alpha_5 = 0$, $\beta_5 = 1$	1.2497	2.9826
p-value	0.5353	0.2251
$\overline{R}^2$	0.3581	0.2746
DW	0.3226	0.1726
Q test	44.577	83.793
p-value	$1*10^{-6}$	0.000000
White's test	5.5639	5.9150
p-value	0.0619	0.0519
Kolmogorov-Smirnov test p-value	> 0.15	> 0.15
Number of observations	38	38

Table 10: Results from some foreign tests of the EH for **short term** interest rates. The model is equation (9) or some variant of it.

Author	Hsu Kugler	Hsu Kugler	Gerlach Smets	Gerlach Smets	MacDonald Macmillan	Froot (T-bills)	Froot (Euro-dollar)
Term			1m3m	1m3m	3m3m	3m3m	3m3m
β	0.158	1.138	0.75	0.40	0.27	0.059	0.427

Standard error	(0.261)	(0.162)	-	-	-	(0.260)	(0.316)
t: β=0	0.6	7.0	0(p-val)	2.6(p-v)	2.0	0.23	1.35
t: β=1	3.22	0.9	24.4(p-v)	0(p-val)	Significant	3.6	1.8
R^2 ($\bar{R}^2$)	0.004	0.45	11.6	9.8	-	0.35	0.02
DW	-		-	-	-	2.06	1.89
Country	USA	USA	Italy	Austria	UK	USA	USA
Time	1973-95	1987-95	1977-93	1978-93	1989-92	1969-86	1969-86

Table 11: Results from some foreign tests of the EH+RE for **long term** interest rates.

Author	Bekaert Hodrick Marshall[41]	Bekaert Hodrick Marshall[4]	Engsted[42]	Froot	Froot	Hardouvelis[43]	Hardouvelis

[41] The regression model is: $r_{t+1}^{t-1} - r_t^t = \alpha + \beta \frac{1}{t-1}(r_t^t - r_t^1) + \varepsilon_{t+1}$. The slope coefficient should equal unity. τ is three- and five years to maturity, respectively, and 1 in r_t^1 is one month.

Term	3y 1m	5y 1m	26w 13w	12m 6m	30y 6m	10y	10y
β	-1.67	-2.320	0.869	-0.122	0.568	0.0522	0.067
Standard error			(0.090)	(0.209)	(0.090)	(0.411)	(0.922)
t: β=0				0.58	4.81		
t: β=1	0.03(p-value)	0.025(p-value)	1.46	5.37	4.82	1.09	1.01
R^2 ($\overline{R}^2$)				0.18	0.47	0.003	0.000
Country	USA	USA	Denmark	USA	USA	France	Italy
Time	1952-95	1952-95	1992-93	1969-86	1969-86	1969-92	1972-92

Table 12: Hörngren's (1986) and Dalquist and Johnson's (1994) regression results from equation (9), respectively.

Hörngren: March 1980-November 1985 Dahlquist & Jonsson:January 1984-July 1992

	1m1m	1m2m	3m3m	1m1m	1m2m	3m3m	6m6m
α	0.00001	0.00008	0.00121	0.001	0.002	0.002	0.004

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[42] The model used is: $\frac{t-k}{k}(r_{t+k}^{t-k} - r_t^t) = \alpha + \beta\ (r_r^t - r_t^k) + \varepsilon_{1,t+k}$. If the EH holds with rational expectations and constant risk premia β should not be significantly different from one. τ is 26 months and k is 13 months.

[6]Hardouvelis uses the following model: $r_{t+1}^t - r_t^t = \alpha + \beta\left[\frac{1}{D_N - 1}\right](r_t^t - r_t^k) + u_{t+1}$. τ and k denote the ten-year and three-month interest rates, respectively. D_N is the duration of the long-term bond. The EH holds if β is not significantly different from one.

Standard error	(0.0001)	(0.00015)	(0.00058)	(0.001)	(0.001)[44]	(0.002)	(0.003)
t: α=0	(0.09)	(0.53)	(2.09)	(1.00)	(2.00)	(1.00)	(1.33)
β	0.4545	0.4188	1.1109	0.918	1.205	1.427	1.347
Standard error	(0.3080)	(0.2339)	(0.3313)	(0.156)	(0.202)	(0.311)	(0.487)
t: β=0	(1.48)	(1.79)	(3.35)	(5.88)	(5.97)	(4.59)	(2.77)
t: β=1	(1.77)	(2.48)	(0.33)	0.53	(1.01)	(1.37)	(0.71)
R^2	0.04	0.05	0.15	0.258	0.293	0.249	0.230
DW	2.32	1.07	0.70				
F-test, α=0, β=1				0.511			
c^2-test α=0, β=1					3.225	2.652	2.271
Number of observations	68	68	68	103	103	103	103

Table 13: Variances of series.

	6m3m	6m6m
fp_t^k	0.000958	0.002649
$E_t(\Delta_{t,k} r)$	0.000770	0.002695

[44]In Dahlquist and Jonsson's study, Newey and West's (1987) standard errors for the coefficients are given in parentheses except for (1m1m).

rp_t^k	0.000554	0.001221
u_t^k	0.001558	0.005683
$\Delta_{t,k}r$	0.001942	0.007673

Table 14: Correlations of series six-month rate three- (6m3m) and six (6m6m) months ahead.

	fp_t^k	$E_t(\Delta_{t,k}r)$	rp_t^k	u_t^k
6m3m				
$E_t(\Delta_{t,k}r)$	0.7471	-	-	-
rp_t^k	0.3777	-0.3334	-	-
u_t^k	0.1405	-0.2268	0.5151	-
$\Delta_{t,k}r$	0.6413	0.4864	0.2321	0.7407
6m6m				
$E_t(\Delta_{t,k}r)$	0.8755	-	-	-
rp_t^k	0.6698	0.2276	-	-
u_t^k	0.1462	-0.0626	0.3909	-
$\Delta_{t,k}r$	0.5424	0.4097	0.4635	0.8849

Table 15: Components of the possible failure of the expectations hypothesis. December 1992-January 1996. The underlined figure indicates the greatest absolute value for each horizon.

Term	Deviations from rational expectations b_{ee} $-\frac{Cov(u_t^k,\ fp_t^k)}{Var(\ fp_t^k)}$	Existence of risk premia b_{rp} $\frac{Cov(rp_t^k,\ fp_t^k)}{Var(\ fp_t^k)}$	Regression coefficients $= 1 - b_{ee} - b_{rp}$
6m3m	-0.1794 (not significant)	0.2663 (significant)	0.91
6m6m	-0.2183 (not significant)	0.3323 (significant)	0.89[45]

Table 16: Results of fitting equation (19) and (21) to data. Newey and West (1989) standard errors are given in parentheses. The standard errors are corrected for overlapping observations.

	6m3m	6m6m

[45] This figure should equal the parameter estimate β_5 in Table 9. The divergence is due to the fact that we use a different number of observations in the time series which are used to perform this calculation.

α_6	0.0020	0.0048
Standard error	(0.0009)	(0.0008)
t: $\alpha_6 = 0$	(2.1871)	(5.6474)
β_6	0.2663	0.3323
Standard error	(0.1206)	(0.0811)
t: $\beta_6 = 0$	(2.2078)	(4.0995)
β_8	0.1794	0.2183
Standard error	(0.1978)	(0.2140)
t: $\beta_8 = 0$	(0.9072)	(1.0210)

Table 17: Components of the possible failure of the expectations hypothesis in Froot's study on U.S. data during the time 1969-1986, Batchelor's study on U.S. data during October 1982-March 1987 and MacDonald/Macmillan's study on UK data during October 1989-October 1992. The underlined figure indicates the greatest absolute premium for each term.

Author	Term	Deviations from rational expectations b_{ee} $-\frac{Cov(u_t^k, fp_t^k)}{Var(fp_t^k)}$	Existence of risk premia b_{rp} $\frac{Cov(rp_t^k, fp_t^k)}{Var(fp_t^k)}$	Regression coefficients $= 1 - b_{ee} - b_{rp}$
Froot	3m3m T-bills	0.338 (not significant)	<u>0.602</u> (significant)	0.059
Froot	3m3m Eurodollar	0.016 (not significant)	<u>0.557</u> (significant)	0.427
Batchelor	3m1m T-bills	<u>0.6413</u> (not significant)	0.3994 (significant)	-0.041
MacD/Macm	3m3m Interbank rate	0.1147 (not significant)	<u>0.5846</u> (significant)	0.268

Figure 2a: Actual- and mean surveyed (expected) six-month rate three months ahead (6m3m).

Figure 2b: Actual- and mean surveyed (expected) six-month rate six months ahead (6m6m).

Figure 3a: Actual vs mean surveyed (expected) interest rates.

Figure 3b: Actual vs mean surveyed (expected) interest rates.

Figure 4a: Forecast errors for the six-month rate three months ahead.

Figure 4b: Forecast errors for the six-month rate six months ahead.

Figure 5a: The actual, maximum and minimum values of the surveyed six-month rate three months ahead.

Figure 5b: The actual, maximum and minimum values of the surveyed six-month rate six months ahead.

Figure 6a: The difference between the maximum and minimum interest rates for the six-month rate three months ahead (6m3m).

Figure 6b: The difference between the maximum and minimum interest rates for the six-month rate six months ahead (6m6m).

Figure 7a: Forward premium, Risk premium and Expected Interest Rate Differential. Six-Month Rate Three Months Ahead (6m3m).

Figure 7b: Forward premium, Risk premium and Expected Interest Rate Differential. Six-Month Rate Three Months Ahead (6m6m).

Figure 8a: Actual and Expected Interest Rate Differential and Expectation Error (6m3m).

Figure 8b: Actual and Expected Interest Rate Differential and Expectation Error (6m6m).

APPENDIX: Calculations

Calculation of continuously compounded interest rates

All interest rates in this study are expressed in continuously compounded form. The starting point for calculating the continuously compounded interest rates is the expression

$$e^{r_0 \frac{d}{360}} = 1 + r\frac{d}{360}$$

where r_0 is the continuously compounded interest rate, r is the annual interest rate and d is the number of days to maturity of a bond. Taking the logarithm of the left- and right hand side we arrive at

$$r_0 = \ln\left[(1 + \frac{r}{100}\frac{d}{360})\right]\frac{360}{d}$$

Calculation of implicit forward rates

When the interest rates are expressed in continuously compounded form the algebra for the forward rates is simple. Let $r_{t+\tau}$ be the continuously compounded interest rate traded at time t and maturing at time τ. Let $f_t^{k,\tau-k}$ be the implicit forward rate at time t for a τ-k period investment that starts at time k and ends at time τ, the maturity date. Then the forward rate is related to the spot rates according to

$$f_t^{k,\tau-k} = \frac{(\tau - t)r_{t+\tau} - (k-t)r_{t+k}}{\tau - k}$$

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