Which model generates the best predictions on the future spot rate?

– a comparison between three different forms of the UIP model.

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Abstract

There are many empirical studies that reject the forecasting power of the uncovered interest rate parity condition. This might be due to different reasons, of which one often stated is the existence of a risk premium. In this paper three variants of the conventional UIP model are tested in order to investigate which one that generates the best predictions on the future spot rate. One model without a risk premium is used, one with a constant risk premium, and one with a time varying risk premium. The predictions are made out-of-sample and built on data on the Swedish exchange rate against the Danish krone, British pound, Japanese yen and the Norwegian krona, as well as the interest rates in these countries during the time period January 1993 until December 2004. The results indicate that the model with a time varying risk premium outperforms the other two models. Concerning the comparison between the model with no risk premium and the model with a constant risk premium, the result has in general a low significance level that might indicate some lack of credibility, but the former one seems to generate the most accurate predictions.

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Summarize

Title: Which model generates the best predictions on the future spot rate? – a comparison between three different forms of the UIP model.

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Purpose: The aim of this paper is to study what impact a risk premium has on the UIP condition. The UIP model is examined in three forms to conclude which one that generates the best predictions on the future spot rate. This is done for the Swedish currency relative to the Danish, the English, the Japanese and the Norwegian currency respectively. The three forms to be studied are the UIP-model with no risk premium, a model with a constant risk premium included, and a model with a time varying risk premium, modelled according to an AR(1)- process.

Method: Introductional regressions are made based on empirical data from January 1993 until December 1999, to make a foundation for the predictions on the difference in exchange rates during a time horizon of three months. Month wise predictions are made out-of-sample until December 2004 for the three models, and it is examined which one that succeed best by comparing the difference in prediction errors for every combination of models.

Keywords: UIP, interest rate, spot rate, risk premium, prediction error.

Conclusions: The model with a time varying risk premium generates the most accurate predictions on the future exchange rate in this survey. The difference between the other two models is not that legible, but the results encourage believing that the model with no risk premium outperforms the one with a constant risk premium.

1 Introduction

Some previous empirical studies of the uncovered interest rate parity condition will be introduced in this chapter. There will also be given account for the purpose and outlook of the paper.

The uncovered interest parity condition (UIP) postulates that the interest rate differential between two bonds in different countries should equal the expected rate of depreciation of the exchange rate. This follows intuitively from the fact that investing in deposits in a foreign country will yield a rate if return corresponding to that country's interest rate. And since we assume a return to equilibrium in the long run, this has to equal the pay-off from a domestic investment. The regression equation on which empirical tests are based on is formulated so that the rate of depreciation, or the change in the log spot rate, equals an intercept plus a slope coefficient times the log nominal interest rate differential between the two current countries. This equation is usually written as $\Delta s_{t+1} = \alpha + \beta(I_t - I_t^*) + \varepsilon_{t+1}$. (Equation 1.1, see chapter 2 for derivation of this expression.)

The null hypothesis on UIP without a risk premium corresponds to an intercept of zero and a slope coefficient of one. This relation is usually rejected in empirical studies though, with the finding of a negative slope coefficient, a rejection stated as the forward premium puzzle by amongst others Philip(2004)[1]. To point out some previous studies of UIP one can mention Hodrick and Baillie (1989)[2], Froth and Thaler (1990)[3] and Engel (1996)[4]. Froth and Thaler (1990) come to the conclusion that the slope coefficient is always smaller than theory suggests, with an average value of -0,88.

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[1] Philip S. Marey, Uncovered interest parity tests and exchange rate expectations (2004) p.2
[2] Hodrick, R.J. and Baillie R.T., The empirical evidence on the efficiency of forward and futures foreign exchange markets (1989)
[3] Froot Kenneth A., and Thaler Richard H., Foreign Exchange (1990)
[4] Engel, The forward discount anomaly and the risk premium: a survey of recent evidence (1996)

Chinn and Meredith (2002)[5] get an average value of -0,8 during the time period 1980 until 2000. Baillie and Bollerslev (2000)[6] and Flood and Rose (2002)[7] have amongst others shown that the coefficient often is positive and in some cases even larger than one during the 1990´s. The former means that these empirical results are suggestive of slow convergence to the true parameter value of one. Meredith and Ma (2002)[8] show nevertheless that the coefficient goes down to below zero again during the latter part of the 90´s. In most of the empirical studies of UIP though, the slope coefficient is negative, which can be interpreted as that the currency with the higher interest rate tend to appreciate[9]. The empirical findings of a negative slope coefficient imply that the rate of appreciation of the spot exchange rate is negatively correlated with the lagged forward premium. This means, as stated by Baillie and Kiliç (2005)[10], that the country with the highest interest rate will have an appreciating currency, and not a depreciating currency, as implied by the theory of uncovered interest rate parity.

Equation 1.1 is based on the joint hypothesis of rational expectations and a constant risk premium, and possible explanations for the forward premium puzzle are hence expectational error and the existence of a time varying risk premium. Studies made to compare the impact of these two factors do not always agree. Fama (1984)[11] comes to the conclusion that, conditional on the hypothesis that the forward market is efficient and rational, most of the variation in forward rates is due to variation in premiums, and that the premium and the expected future spot rate components of forward rates are negatively correlated. This is an argument for using a time varying risk premium when making predictions. Also Hodrick and Srivastana (1984)[12] find evidence consistent with time varying premiums, and that the conditional expectation of the risk premium is a nonlinear function of the forward premium. Furthermore, some have shown that a time varying risk premium play an important role in addition to expectational error, and some that the time varying risk premium plays a minor role[13]. Flood and Rose (2002)

[5] Chinn, M.D. and Meredith, G., Testing uncovered interest parity at short and long horizons during the post Bretton Woods era (2002)
[6] Baillie, R.T. and Bollerslev T., The forward premium anomaly is not as bad as you think (2000)
[7] Flood, R.P. and Rose, A.K., Uncovered interest parity in crisis (2002)
[8] Meredith G. and Ma Y., The forward premium puzzle revisited (2002)
[9] Chaboud Alain P., Wright Jonathan H., Uncovered Interest Parity: it works, but not for long (2003)
[10] Baillie R. T. and R. Kilic, Do asymmetric and nonlinear adjustments explain the forward premium anomaly (2005)
[11] Fama E.F., Forward and spot exchange rates (1984)
[12] Hodrick Robert J., Srivastana S., An investigation of risk and return in forward foreign exchange (1984)
[13] Philip (2004), p.3

come to the conclusion that the UIP test coefficients have negative values for fixed and flexible exchange rates, but positive for crisis countries that have experienced a regime shift, indicating an improved performance of UIP for crisis countries. Chinn and Meredith[14] show amongst others that UIP performs better for longer time horizons. Furthermore, Baillie and Kiliç (2005) argue that there is a trade-off between interest-rate smoothing monetary policy and uncertainty in predicting the exchange-rate.

Although the theory of the UIP condition is so widely spread and investigated, the assumption based on it does not hold very well in empirical studies. The model has great weaknesses in predicting the future spot rate, and according to some the best method to use is a prognosis model that simply assumes that the spot rate tomorrow will equal the rate today.

In this paper the impact of a risk premium will be further investigated, and the UIP condition will be studied in three different forms; in its most basic form without a risk premium, with a constant risk premium and finally with a time varying risk premium, to investigate which of the three that generates the best predictions. The base is hence the same for all three models, but for the latter two we make some extensions by adding further variables. In the simulations simple regression technique will be used and the purpose is to test the robustness of the relationship between the prevailing nominal exchange rates and the outcome of the uncovered interest parity tests. The predictions will be made out-of-sample, which means that a model is estimated using observations up to a point in time, t, and predictions are then made for $T > t$. This method differs from the in-sample method[*] in such a way that adding more variables could cause the model to perform more poorly. I will use actual observed data for the interest differential though, when making the predictions on the future exchange rate differential.

UIP is always used for land pairs and here the Swedish krona will be studied relative to the following currencies; the Danish krone, the Great Britain pound, the Japanese yen and the Norwegian krona. The background for choosing Sweden as the reference country is simply because the writer is Swedish and that the paper is written in Sweden.

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[14] Chinn, M.D. and Meredith, G., Long-horizon Uncovered Interest Parity (1999)
[*] Estimating a model with observations until a certain time t, and check how well it predicts for the period $T<t$, by residual analysis. This will never perform more poorly by adding more explanatory variables.

Concerning the other countries, it was regarded as interesting to investigate the Swedish currency relative to some other Scandinavian countries as Denmark and Norway, and furthermore it felt naturally to look at the Great Britain pound and the Japanese yen since those are great economies and countries that Sweden has a lot of trade with.

The remainder of this paper is organized as follows. In chapter two some theory involving the uncovered interest rate parity condition will be clarified, and the implications of an existing risk premium will be briefly explained. In chapter three the three versions of the UIP models that are being used in the study will be given account for, and the reason for using an AR(1)-process to describe the time varying risk premium will also be enlightened in a few words. Chapter four contains of a description of the empirical data used in the investigation, and an elucidation of the method. In chapter five the results from the uncovered interest parity tests will be presented. Firstly the results for the initial regressions on which the predictions are based will be shown. This is followed by a comparison between the accuracy of the predictions for every combination of models. In chapter six you will find the conclusions of the paper.

2 Theory

In this chapter the UIP-model will be derived and its significance explained. There will be given account for the implications of an existing risk premium and what a risk premium involve.

2.1   Derivation of the UIP-model

For UIP to apply certain prerequisites needs to be fulfilled. We assume that bonds yielding interest rates I_t and I_t^* (where * indicates the foreign bond) are perfect substitutes. This involves two things; we assume that capital is perfectly mobile, which means that an investor can switch between the two assets instantaneously, which is likely, and that the bonds are equally risky, *or* that the investor is risk neutral, which is more doubtful. If these conditions are fulfilled, the only difference between the two bonds is their currency and the interest rate attached to them. Suppose the investor chooses to buy the domestic bond, let us call this alternative one, it will rise in value by a factor of $(1 + I_t)$ until the next time period. If the investor instead chooses to buy the foreign bond, which is alternative two, the investment has to be converted into foreign currency, and we let S_t denote the spot exchange rate at time *t,* the rate at which we can purchase or sell domestic currency at that time (expressed as domestic currency units per unit of foreign currency). We easily see that the investor will have $(1 + I_t^*) \cdot \dfrac{1}{S_t}$ units of foreign currency the next period. If we now convert this back at the rate that we expect will prevail this next period, the forward exchange rate, say s_{t+1}^e (the rational or efficient forecast at what price we can buy and sell in the future, conditional on all information available at *t)*, we get the expected outcome of the second alternative as $(1 + I_t^*) \dfrac{1}{S_t} \cdot S_{t+1}^e$. The forward exchange rate is usually defined as the rate that appears

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in contracts that stipulate the exchange of a currency for another in advance of the actual transaction. Eventually, the following relationship will hold:

$$(1 + I_t) = (1 + I_t^*) \frac{1}{S_t} S_{t+1}^e \qquad (2.1)$$

The approximation that $i_t = \ln(1 + I_t) \approx I_t$ holds fairly well for small interest rates, and we can now state the uncovered interest parity condition (UIP) by taking logs:

$$\Delta s_{t+1}^e = I_t - I_t^* \qquad (2.2)$$

Δs_{t+1}^e is the change in the log nominal exchange rate between the period t and $t+1$. This is hence the expected rate of depreciation during that time period $(s_{t+1}^e - s_t)$.

2.2 The existence of a risk premium

Investing in bonds in different countries is in general not viewed as being equally risky. If it does not hold that bonds are equally risky, there is a risk premium. This means that investors that are risk-averse and regard domestic bonds as being more risky relative to foreign bonds, will require a higher expected return on domestic bonds than foreign bonds. This additional expected return is known as the risk premium. A risky asset is defined as one whose expected real rate of return is uncertain. We redefine the model in 2.2 to contain this risk premium as:

$$\Delta s_{t+1}^e = rp_t + \beta(I_t - I_t^*) \qquad (2.3)$$

where rp_t represents the risk premium. Under rational expectations[#] uncovered interest parity implies that $\beta = 1$[15], and generally, the null hypothesis tested is that $rp_t = 0$ and $\beta = 1$. Under that null hypothesis, the log of the forward rate provides an unbiased forecast of the log of the future spot exchange rate. The existence of a risk premium

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[#] The assumption that agents make no systematic prediction errors is called the assumption of rational expectations.
[15] Philip (2004), p.2

makes the model hard to test, since we can not observe neither the risk premium, nor the expected rate of depreciation. In order to test for the existence of a risk premium we must assume that the efficient market hypothesis (EMH)[#] holds and that agents have rational expectations. For a risk premium to exist the following conditions must be fulfilled[16].

1. There must be noticeable differences in risk between domestic and foreign bonds. If an asset is considered risky its expected real rate of return is uncertain.
2. The investors have to be risk-averse to the perceived differences in risk. They will only be willing to take the higher risk if there is a sufficient increase in expected real returns to compensate.
3. Given there is a risk-minimizing portfolio, there must be a difference between this and the actual portfolio forced at market clearing prices. If this risk-minimizing portfolio is not held, agents will demand a risk premium to compensate.

If all of theses conditions are fulfilled, a risk premium exists and the UIP-condition according to equation 2.2 will not hold. The expected rate of return on domestic bonds may be higher, generating a positive risk premium, or the other way around, generating a negative risk premium, when compared to foreign bonds.

2.3   Different types of risks

Investors are assumed to be rational, in the sense that they have rational expectations and try to maximize their expected utility. We presuppose that they will choose their portfolios such that they are an optimum combination of expected rate of return and risk, given their individual risk-return preferences. The less risk-averse investors are, the more likely they are prepared to take a risk. Risks can be subcategorized into two main groups; currency risks and country risks[17].

[#] An efficient market is conventionally defined as one in which the prices always fully reflect available information (Pilbeam, p.214)
[16] Pilbeam Keath, International Finance, 2nd edition (1998) p.187
[17] Pilbeam, p.189.

2.3.1 Currency risks

This can be further subcategorized into inflation risk and exchange risk. *Inflation risk* is a consequence of the uncertainty of the inflation rates. According to the purchasing power parity (PPP) it applies that if the expected domestic inflation rate is uncertain, the real rate of return on domestic bonds will also be uncertain. The absolute version of the PPP theory can be stated as $S = \dfrac{P}{P^*}$ where S is the exchange rate, defined as domestic currency units per unit of foreign currency, P is the price of a bundle of goods expressed in the domestic currency and P^* is the price of the same (or very similar) bundle in the foreign currency. The risk of holding a domestic bond can therefore be represented as a positive function of the variance in the domestic inflation rate, and for the risk of holding a foreign bond the condition is the directly correspondent.

If we assume that inflation and domestic and foreign interest rates are equal and exchange rates are initially in PPP, an expected real depreciation of the currency in terms of PPP means that there is an expected real appreciation of the foreign currency. This is called e*xchange risk* and implies that there is an increased expected return from holding foreign bonds. Hence; fluctuations in the exchange rate that cause deviations from PPP constitute a risk specific to foreign investment.

2.3.2 Country risks

These types of risks can be divided into three groups; exchange control risk, default risk and political risk. *Exchange control risk* means that the real rates of return on bonds may face some uncertainty due to the risk of the imposition of a tax on the investment during the holding period. This risk might be differently great between the domestic and foreign bond.

The *default risk* is a more serious risk, involving the case where the government refuses to pay interest in bonds issued by them and denominated in a foreign country.

And finally we have what is called a *political risk.* This risk covers a broad range on scenarios, referring to the risk that investors, due to the political environment in the country, may lose parts of their investments or face costly restrictions.

These are the risks that investors face and consider if they are assumed to have rational expectations. They thus result in the existence of a risk premium, meaning that investors will expect a higher rate of return if any, or a combination, of the risks above are present or to be expected.

2.4   The time varying risk premium

In this survey a constant as well as a time varying risk premium will be examined. A model with a constant risk premium describes the case when the risk does not change during the time period conserned, whilst a time varying risk premium can be a result of either a constant risk but different requirements on compensation, *or* of varying risk but constant requirements on compensation. It is also possible with a combination of these two latter occurrences. Agents will in many cases not hold static expectations, which is what the rational expectation hypothesis says. We assume that agents have rational expectations though, and deviations from the basic UIP condition are interpreted as a consequence of an existing risk premium. Assuming rational expectations implies that we consider the risk premium in the UIP formula to occur as a consequence of expectational error. True deviations arise when the errors take different forms in time. The risk premium can hence be seen as a prediction error in the UIP model. If we cannot systematically assume rational expectations, we have a prediction error. One could consequently denote the existence of a time varying risk premium as that the rational expectation hypothesis does not hold. The expectations will instead be of adaptive, extrapolative and regressive character. Agents are said to hold *adaptive expectations* if they adjust their previous exchange rate expectations in the direction of the most recently observed exchange rate. Under adaptive expectations the uncovered interest parity test coefficient, β tends to be negative, but Philip (2004) show that the adaptive expectations markets are able to generate both negative and positive values for β. If an agent has what is called *static expectations*, he or she will expect the exchange rate to remain at the current level. Note that in this case the risk premium

must be time varying and identical to the interest differential for the uncovered arbitrage condition in equation 2.3 to hold.

In this chapter it has been given account for the most essential theory for the study of current interest. Some different kinds of risks have been explained and in the last part the implications of the existence of a time varying risk premium have also been stated. In the survey rational expectations are assumed, as mentioned before.

3 The econometrical models

In this chapter the equations for the three models to be used are formulated, and it is described how the predictions are made.

3.1   Specifications of the models to be studied

Three forms of the UIP model will be studied in this paper. Here follows a description of these and how they are implemented in the study. In the calculations I have chosen not to use the approximation that $i_t = \ln(1 + I_t) \approx I_t$ as described in chapter 2. I have instead used $\ln(1 + I_t) - \ln(1 + I_t^*)$ on the rhs in equation 2.2. In the same way the real exchange rates for the three month interval are calculated as $\ln(S_t) - \ln(S_{t+3})$.

3.1.1   UIP with no risk premium

The most basic UIP model without a risk premium is simply formulated as:

$\ln(S_t) - \ln(S_{t+3}) = \ln(1 + I_t) - \ln(1 + I_t^*)$, which corresponds to

$$\Delta s_{t+1}^e = \beta(i_t - i_t^*) + e_t \qquad\qquad \text{(Model 1)}$$

According to theory a regression of exchange rates on the interest differential should give a slope coefficient of one. The initial regression is made on the data from January 1993 until December 1999. The slope coefficient, $\hat{\beta}$, for this last observation is used to predict the difference in exchange rates for the next time period as $\hat{\beta}$ times the interest differential. Thereafter a new estimation is made, including an additional observation, on which the following prediction is based, and so on.

3.1.2 UIP with a constant risk premium

We now add a constant risk premium to the basic model above, and formulate this as:

$$\Delta s_{t+1}^e = rp + \beta(i_t - i_t^*) + e_t \qquad \text{(Model 2)}$$

If consistent with theory this model will generate an intercept of zero and a slope coefficient of one. An initial regression is made as for model 1, giving the estimated intercept, $\hat{rp}$ and slope coefficient $\hat{\beta}$. A prediction for the nest time period is then calculated as $\hat{rp} + \hat{\beta}(i_t - i_t^*)$. This is then repeated for every time period until December 2004 in the same way as described above.

3.1.3 UIP with a time varying risk premium

We now let the risk premium vary in time. In practice we accomplish this by letting it vary according to an AR(1)-process (*described below*):

$$\Delta s_{t+1} = rp_t + \beta_1(i_t - i_t^*) + e_{1,t} \qquad \text{(Model 3a)}$$

The specification for the time varying risk premium is formulated as

$$rp_t = \beta_2 + \beta_3 \cdot rp_{t-1} + e_{2,t}. \qquad \text{(Model 3b)}$$

Model 3b describes the AR(1) process, and $e_{1,t}$ and $e_{2,t}$ are the error terms for the UIP condition with time varying risk premium and for the AR(1) process respectively. Considering the error terms it is assumed that $\text{cov}(e_{1,t}, e_{2,t}) = 0$ and $\text{var}(e_{2,t}) = 1$. In order to estimate the model uniquely and to be able to identify the parameters, the normalized variance for rp_t is set to one. When making the predictions for the future exchange rate $\beta_1(i_t - i_t^*) + \beta_2 + \beta_3 \cdot rp_{t-1}$ is calculated. This is repeated for every time period like before. Of course, one should be aware of the fact that an AR(1)- process, though presumingly being one of the best way to describe a time varying risk premium, only is an approximation of how this might appear.

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4 Data and method

4.1 Empirical data

In the paper the nominal spot exchange rates between Sweden and Denmark, Norway, Great Britain and Japan respectively are being tested. Exchange rates are measured as home currency per unit of foreign currency, here as Swedish kronorss per unit of the currencies for the countries above. The difference in exchange rates faces a time horizon of three months in the paper, and the chosen interest rates as well as the spot exchange rates are the average of the observed values for each month. Nominal exchange rates and key interest rates from January 1993 till December 1999 is the foundation for the initial estimations on the intercept and slope coefficients. This generates a foundation for making the predictions for the expected rate of depreciation during the time period October 1999 till January 2000. The data comes from the Swedish Riksbank (the National Bank of Sweden)[18].

4.2 Method

Based on the opening regressions month wise predictions are made, and noted, until December 2004, which gives a final prediction for the difference between the log spot rates from October till December that year. We hence get the out-of-sample predictions, described in the introduction of this paper. I use seven years of data when making the initial regression, resulting in 81 observations ($7 \cdot 12 - 3$), and the predictions in the survey are based on 60 observations ($5 \cdot 12$).

In the predictions we assume that agents adjust their previous exchange rate expectations in the direction of the most recently observed exchange rate, what is known under the name adaptive expectations. For every new prediction, the initial models are estimated once again, increased with data from the last month. Hence every

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[18] http://www.riksbanken.se/templates/stat.aspx?id=16747 and
http://www.riksbanken.se/templates/stat.aspx?id=16736 collected during 2005-11-10 until 2005-12-01.

prediction is based on this latest estimation. This is repeated 60 times for every additional month until December 2004. These predictions are then compared to the real values of the log nominal exchange rate differential for the three-month horizon by making forecast error series according to $(\Delta s - \Delta \hat{s})^2$, where $\Delta \hat{s}$ represents the difference in the predictions of the future spot rate, also here of course for a three month horizon. Subtractions on the deviations between each combination of the different models are constructed, i.e. according to $(\Delta s_t - \Delta \hat{s}_t)^2{}_{no\,rp} - (\Delta s_t - \Delta \hat{s}_t)^2{}_{const\,rp}$, and regressions of these differences are then run with an intercept as explanatory variable. The significance and sign of this intercept will tell if the difference is statistically significant and which of the two compared models that has the smallest forecasting error. A five percent significance level is used throughout the investigations.

5 Results

Results will be shown for the estimations using observations from January 1993 until December 1999, and predictions are then made based on these models for the time period 2000 until 2004. Finally comparisons between the results for the three models will be shown.

In the first part of the chapter the results from the regressions which the initial predictions are based on will be presented. This covers exchange rates and interest rates for the period from January 1993 until December 1999. Since the regressions are run on the change in the log nominal spot rate during a three month horizon, the last observation for each sample is the difference between observations from December and September 1999. The first prediction is consequently the difference in exchange rates between January 2000 and October 1999, which corresponds to the rate of depreciation during this time. For every new prediction to be made, the models are estimated as before, but with an additional month added to the observations. The next prediction is based on the results from this estimation. This procedure is repeated for every additional prediction to be made, every time adding the following month to the estimating regression.

To investigate which of the models that generates the most accurate predictions, the results from the comparisons between the models are shown. They are compared by running regressions on the difference in their squared prediction errors. This is done by constructing subtractions for the squared deviations for each combination of models. The results will be presented for each model in the sections below. In the tables the variables next to the countries Denmark, England, Japan and Norway denote the relationship between the Swedish currency and that country's currency. All exchange rates are expressed as Swedish kronorss per unit of foreign currency. *(Comparative graphs of the predictions for the different countries can be viewed in appendix.)*

Sometimes it will be referred to model 1, 2 and 3 in the following text, I then imply the model with no risk premium, constant risk premium and time varying risk premium in that order, as derived in chapter 3.

5.1 Samples used to make predictions

Table 1 below illustrates the estimated regressions of model 1, and the t-statistics as well as the probability value and adjusted coefficient of determination for each country.

Table 1: UIP regressions without a risk premium, model 1.				
Coefficient estimates (Standard errors in parentheses)				
Period Jan 1993 – Dec 1999				
Country	Coefficient	t-Statistic	Prob.	R^2
Denmark	-0.256605 (0.194875)	-1.316770	0.1917	0.020429
England	-0.433139 (0.197543)	-2.192629	0.0312	0.021957
Japan	0.019423 (0.166399)	0.116724	0.9074	-0.014987
Norway	-0.291693 (0.171484)	-1.700998	0.0928	0.034280

All of the slope coefficients are invariably less than the expectation of unity, and they are all negative except for the Japanese yen. Only the coefficient for England though is significant on a five percentage level, and for Norway it is significant on a ten percent level. The coefficients for the remaining countries are not significant. Also note that the coefficient of determination is low, indicating that only a few percents of the variation in log exchange rates can be attributed to the difference in the log interest rates. (The negative sign for R^2 for Japan is a consequence of the fact that the model does not contain an intercept term.) The sign and size of the coefficients match previous studies of the uncovered interest parity where in general the test coefficient tends to be negative under adaptive expectations, but one should not jump to conclusions based on these results, since the model seems to perform rather poorly. The fact that this simple regression model does not seem to hold indicates that there is a risk premium.

In table 2 we will see the corresponding results from the estimated regressions of model 2.

Table 2: UIP regressions with a constant risk premium, model 2.					
Coefficient estimates (Standard errors in parentheses)					
Period Jan 1993 – Dec 1999					
Country	Variable	Coefficient	t-Statistic	Prob.	R^2
Denmark	Intercept	0.066473 (0.399658)	0.166324	0.8683	0.020772
	Slope	-0.267425 (0.206579)	-1.294537	0.1993	
England	Intercept	0.735607 (0.427977)	1.718799	0.0896	0.057213
	Slope	-0.427405 (0.195202)	-2.189548	0.0315	
Japan	Intercept	10.67504 (2.810763)	3.797917	0.0003	0.141722
	Slope	-1.992390 (0.551641)	-3.611750	0.0005	
Norway	Intercept	0.126200 (0.383627)	0.328965	0.7431	0.035601
	Slope	-0.310879 (0.182042)	-1.707727	0.0916	

In contrast to the result in table 1, the coefficients for Japan are now significant on a five percent level. For England we see once again relatively high significance, the slope coefficient is significant on a five percent level and the intercept on a ten percent level. For the other countries the coefficients are not significant (other than the slope for Norway, on a ten percent level). The intercept (risk premium) is positive for the regressions for every exchange rate, and for Japan and England significantly different from the prospect of zero, on a five and ten percent level respectively. The slope coefficients are all negative, and also less than one, except for Japan, where the value is significantly -2. One can note that since the risk premium is positive, the expected rate of return on domestic bonds seems to be higher relatively to foreign bonds. The intercept actually has a larger value, the more negative the slope coefficient is.

The results from the regressions of model 3 for the first sub period are shown in table 3 below. I here choose to illustrate only the coefficient values, their standard errors and their probability values, since the other factors are of minor interest.

Table 3: UIP regressions with a time varying risk premium, model 3.
Coefficient estimates (Standard errors in parentheses)
Period Jan 1993 – Dec 1999

Country	β_1	β_2	β_3	rp_t	$\hat{rp}_{t+1}$
Denmark	-0,191331	-0,002101	0,80578	-0,527136	-0,42686
	(0,199934)	(0,118739)	(0,072611)		
Prob.	0,3386	0,9859	0.0000		
England	-0,562123	0,101302	0,900271	0,497138	0,548861
	(0,36502)	(0,10707)	(0,042701)		
Prob.	0,1236	0,3441	0.0000		
Japan	-2,237296	0,808416	0,936328	12,87992	12,86825
	(0,733549)	(0,506446)	(0,038071)		
Prob.	0,0023	0,1104	0.0000		
Norway	-0,40884	0,044833	0,763255	-0,460582	-0,30671
	(0,226352)	(0,134511)	(0,091262)		
Prob.	0,0709	0,7389	0.0000		

The key coefficient to be regarded is β_1 (see specification for model 3 in section 3.1.3). In general the probability values for this coefficient are smaller (closer to *0,05*) than we have seen before, and Japan and Norway show the highest significance levels. This is a vague reason though to believe that the coefficients should now be more reliable. The values for the β_1-coefficients are all negative, as most of the previous results have shown, and Japan's are the smallest (and also the most significant), with a value of -2,24. The values in the right column, the prediction of the time varying risk premium in the following time period, are calculated according to the specification of model 3b (see chapter 3). These are the values of current interest for the first prediction to be made in the next section. This is the case for all the results that are shown in the tables above.

It should be noted that the values for Japan are somewhat deviant from the others in the above tables. One explanation for this occurrence might be that the spot rate between the Swedish krona and the Japanese yen has varied more than the other exchange rates during the observed time period (see diagram 3 in appendix), which probably makes it more difficult to predict. (See further discussion below.)

Based on the estimated values above, the very first prediction is made for the difference in the log spot rate between January 2000 and October 1999. For the next prediction, a new estimation is made with an additional month included, and so on until the last month in the study, December 2004.

5.2   Comparison between the models

For each model the squared deviations are calculated as $(\Delta s_t - \Delta \hat{s}_t)^2$ where $\Delta \hat{s}$ represents the predicted difference in future spot exchange rate. The difference between these deviations is then constructed as $(\Delta s_t - \Delta \hat{s}_t)^2{}_{no\,rp} - (\Delta s_t - \Delta \hat{s}_t)^2{}_{const\,rp}$ for example, as described in chapter 4.2. A regression of this difference with only an intercept as explanatory variable should consequently result in an intercept with positive sign if the latter model, the model with a constant risk premium, generates predictions with smaller squared deviations. This is made for the combinations; *no rp – const rp, no rp – var rp* and finally for *const rp – var rp*. Autocorrelation or heteroskedasticity might occur in the prediction errors and this could affect the standard errors. To correct for these occurrences Newey-West's estimator has been used.

5.2.1   No risk premium vs. constant risk premium

The dependent variable in the following section is the squared deviations for *no risk premium* subtracted with the squared deviations for *constant risk premium*, $(\Delta s_t - \Delta \hat{s}_t)^2{}_{no\,rp} - (\Delta s_t - \Delta \hat{s}_t)^2{}_{const\,rp}$. Results are shown in table 4.

The negative signs for most of the coefficients imply that the squared deviations in model 2 is larger that those from model 1 (see appendix, the difference is actually very

small), and consequently that model 1 exceed model 2 in making more accurate predictions. If the models were equally good (or equally bad) the coefficients would be zero or very close to zero. This is the case for Denmark, which also has the only positive coefficient (noticeable though is that the probability value is large, which is a reason for not jumping to conclusions. This is also the case for the coefficient for Norway). The significantly negative signs for England, and above all for Japan, hence indicate that model 2 does not perform better than model 1. The predictions by the two compared models are not that volatile, in the sense that they do not change much in time, but lie on an almost constant level. For Japan though, the predictions made by the model with a constant risk premium behave more volatile than the predictions by the model without a risk premium. For the other countries the predictions behave very similar over the time period (see appendix).

Table 4: Regression on the squared deviations for model 1 subtracted with the squared deviations of model 2 as the dependent variable.

(Standard errors in parentheses)[*]

	Coefficient	t-Statistic	Prob.	Uncentered R^2
Denmark	0.036631 (0.159019)	0.230357	0.8186	0,001982
England	-0.749431 (0.385007)	-1.946537	0.0564	0,060495
Japan	-8.834940 (3.137449)	-2.815963	0.0066	0,120744
Norway	-0.106254 (0.117027)	-0.907937	0.3676	0,013781

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[*]The uncentered R^2 has been calculated according to $\dfrac{\sum_{i=1}^{N} \hat{y}_i^2}{\sum_{i=1}^{N} y_i^2}$ in the following tables, where the numerator is the squared coefficient value times the number of observations (60) and y_i^2 represents the estimations of the squared differences between the two models prediction errors.

5.2.2 No risk premium vs. time varying risk premium

In table 5 below we can see the results from a regression with the squared residuals for *no risk premium* subtracted with the squared deviations for *time varying risk premium* as the dependent variable, $(\Delta s_t - \Delta \hat{s}_t)^2_{no\ rp} - (\Delta s_t - \Delta \hat{s}_t)^2_{tv\ rp}$.

Table 5: Regression on the squared deviations for model 1 subtracted with the squared deviations of model 3 as the dependent variable.
(Standard errors in parentheses)

	Coefficient	t-Statistic	Prob.	Uncentered R^2
Denmark	1.025424 (0.541760)	1.892765	0.0633	0,090599
England	2.269723 (1.037154)	2.188415	0.0326	0,080249
Japan	-2.890573 (3.197496)	-0.904011	0.3697	0,013666
Norway	2.803012 (0.875562)	3.201387	0.0022	0,148001

For all countries except for Japan, the coefficient is positive, and sufficiently larger than was the case in table 4. Since the probability value is small for most of the regressions, we can not reject the hypothesis of smaller deviations for the time varying model on at least a seven percentage significance level. The coefficients for England and Norway are significant on a five percent level, which is also almost the case for the coefficient for Denmark. For Japan though, we see that we do not have a significant coefficient. Based on these results we conclude that model 3 predicts the future spot rate more accurate than model 1.

5.2.3   Constant risk premium vs. time varying risk premium

In table 6 the results from a regression with the squared deviations for *constant risk premium* minus the squared deviations for *time varying risk premium* as the dependent variable, $(\Delta s_t - \Delta \hat{s}_t)^2{}_{const\,rp} - (\Delta s_t - \Delta \hat{s}_t)^2{}_{tv\,rp}$ will be shown.

These results clearly speak for the fact that model 3 is more successful in making the predictions than model 2. Every coefficient is significantly positive on a five percent level. Once again the coefficient for Japan stands out, in a way that its value is far bigger than for the other coefficients. Obviously model 3 performs substantially better than model 2 especially for Japan, which one can also see by looking at figure 3 in the appendix. For Denmark the difference between the two model's performances is smaller than for the other countries. The graph in figure 1 in appendix shows us that the predictions for the model with time varying risk premium is more volatile in its movements, following the actual spot rate difference more accurate, than the model with a constant rp. One explanation to why the difference still is not that big for Denmark according to the result will follow below.

Table 6: Regression on the squared deviations for model 2 subtracted with the squared deviations of model 3 as the dependent variable.

(Standard errors in parentheses)

	Coefficient	t-Statistic	Prob.	Uncentered R^2
Denmark	0.988793 (0.461272)	2.143623	0.0362	0,108809
England	3.019154 (1.109875)	2.720264	0.0086	0,118828
Japan	5.944368 (1.860726)	3.194649	0.0022	0,15356
Norway	2.909265 (0.871419)	3.338538	0.0015	0,158896

5.3 Discussion

In the comparative tables above we have seen that the coefficient for Denmark has a consistently low value and that the coefficients for Japan somewhat differ from the others. Concerning Denmark, the exchange rate between the Swedish and the Danish krone is the one that has varied the least of the exchange rates in the survey. This is a possible explanation to the fact that the least volatile predictions, those originating from model 1, does not perform as poorly for the Sweden- Denmark exchange rate, as for the exchange rate for the other countries. This can also explain the fact that Denmark has the only positive coefficient in table 4, in the comparison between model 1 and model 2 that are both not very volatile. You might reach a better comprehension to this discussion by looking at figure 1 in appendix.

Concerning Japan, the economy has faced major depreciation during the end of the 90´s, and was under some time in an economic recession. The value of the yen fell, unemployment rose and purchasing of goods went down. In the early 90´s investments began to fall and asset values sank considerably. In an attempt to face these problems the Bank of Japan introduced a zero interest rate policy, until the interest rates were raised again in August 2000. The stock market fell and the risky shares owned by the banks made them lose more money. This instable economic situation discouraged foreign investment, and agents would find investing in Japan risky during those years[19]. The investments followingly also had a low expected rate of return. This leads us to believe that the actual risk premium in Japan has been higher during the last years than is normally the case, since the risk of holding a foreign bond can be represented as a positive function of the variance in the inflation rate, which has varied relatively much in Japan during the investigated period. We also know that risk-averse agents are only willing to take higher risks if there is an adequate increase in expected real returns to compensate. The unstable economic situation in the country might consequently explain why the results from the regressions on Japan in many cases differ from the other countries.

One could perhaps wonder why the model with time varying risk premium clearly performs better than the model with a constant rp, but not that clearly better than the

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[19] Economic conditions of Japan, http://www.wowessays.com/dbase/ab5/lvt78.shtml

model without an rp, according to the results in table 5 and 6 above, though admittedly the only deviant coefficient in table 5 is the one for Japan, and it is not yet significant. A possible explanation is that model 3 follows the true spot rate 'faster' than model 2. Model 1, on the other hand, one find on a rather static level. With this in consideration, it is reasonable that model 1 at some rare points actually could outperform model 3, which needs some time to adjust to the actual spot rate curve. We can note that the coefficient for Denmark in table 5 is positive, but rather small, and not with as high significance as the coefficients for the other countries. Concerning the value for Japan in table 5, there are some implications that model 1 performs better than model 3, although the coefficient is not significant. It is possible that an AR(1) process is not suitable to describe the risk premium for Japan, and that the model actually performs so poorly that it is better to model it without a risk premium.

Especially for Denmark and England one can in the graphs in appendix note that the predictions by model 3 follow the path of the actual observed exchange rate with a lag. This lag probably contributes to the fact that the prediction errors are large at times, though the model clearly seems to follow the pattern for the spot exchange rate curve in a more accurate way than any of the others (see Japan, model 1 and model 3 for example). In Japan's case the average of the predictions of the exchange rate differential originating from model 1 are also closest to the average of the real exchange rate differential, which is interesting to note.

The predictions in the survey are based on 60 observations ($5 \cdot 12$). I use seven years of data when making the initial regression, which results in 81 observations ($7 \cdot 12 - 3$). Those are then increased with additional observations for every prediction. For model 3 we lose some degrees of freedom when making the initial regressions to found the predictions on (see table 3), which can be a reason to the low significance level for some of the variables. One could of course separate the data differently, in such a way that the first estimated model consists of fewer observations, so that the predictions get a higher number of observations. It would indeed be interesting to investigate whether this would generate different results and in what way. It could be worth mentioning that the predictions ought to be more accurate in the end of the sample period, since more and more observations are added to the estimations successively.

To sum up model 3 clearly seems to make more accurate predictions than any of the other two models. Particularly in comparing model 3 and model 2, we noted that model 3 was significantly more precise in predicting the exchange rates for all countries in the survey. Comparing model 3 and model 1 we saw that the only deviating value occurred for the coefficient for Japan, whilst all the others were significantly positive. The contrast between model 1 and model 2 is smaller than between the other combinations of models, but model 1 seems to perform better.

6 Conclusions

As was discussed in the introduction, various explanations have been offered for the finding of the rejection of the uncovered interest parity condition. One explanation is the existence of a risk premium, and this paper has addressed the forward premium puzzle from this perspective. Three models of the uncovered interest rate parity condition have been used; one without a risk premium, one with a constant risk premium and one with a time varying risk premium. The performances of these three models are compared by making predictions on the exchange rate between the Swedish krona and the Danish krone, the English pound, the Japanese yen and the Norwegian krona respectively. I look at the average of every months spot rates and the average of the interest rates and investigate the depreciation in the spot rates during a three month horizon. There are a number of empirical and theoretical reasons that support the existence of a risk premium and in this paper I find that an uncovered interest parity model with a time varying risk premium included generates the best predictions on the difference in future spot exchange rates on a three month horizon.

The difference in the quality of the predictions between the first two models is hardly noticeable in my survey, but the third version outperforms the other two. The biggest difference noted was between model 2 and model 3, where the deviations originating from model 3 consistently is significantly smaller than those originating from model 2. The comparison between model 1 and model 3, is also significantly speaking in model 3´s benefit, except in the case for Japan, which does not have a significant coefficient. The contrast between model 1 and model 2 is smaller than between the other combinations of models, but model 1 seems to perform better. We have a lagged effect in the predictions, and model 3 is the fastest to adjust to the actual value of the spot exchange rate. Model 1 on the other hand find itself on a rather constant level throughout the sample period, which contributes to the fact that it at some points in time will have the smallest distance to the actual exchange rate.

We have seen that the coefficients for Denmark is generally more modest than for the other countries, which is explained by the fact that the spot exchange rate between the

Swedish and the Danish currencies has not varied as much as the other spot rates during the time period I have looked at. We also noticed that the values for Japan often differed somehow from the other values. One reason for this, I concluded, is that the Japanese economy has been very instable during the past recent years, a fact enclosed with agents finding it risky to invest in this country and its currency, relative to the risk attached to the other countries in the survey. This fact makes the spot rate harder to predict, and possibly the AR(1) process is not a successful way to model the Japanese market.

In the tests the three month difference between spot rates has been examined. Further studies in this area should shed lights on different lengths of this time horizon, such as 1, 6 and 12 months as well. These time horizons are conventionally of interest in these types of studies, and looking at different lengths could also enlighten the variation of significance of the three models during shorter and longer intervals. It would also be of interest to model the constant risk premium in some other way than with the AR(1) process. Furthermore I refer to rather simple econometrical models in this study, and a desirable extension would consequently be to extend the econometrical theories. I have for example made some assumptions necessary to be able to identify the parameters of the model with time varying risk premium, such that I put the normalized variance for the risk premium to one.

Although the theory of the UIP condition is widely spread and investigated, the assumptions based on it does not seem to hold very well in empirical studies in general, and also in this survey the models studied hold rather poorly. It is therefore a rather interesting fact that UIP though its flaws is so broadly spread and well known. Maybe the best way to predict the future spot rate is also the simplest; to assume that the spot rate tomorrow will be the same as it is today.

References

Articles and books

Baillie, Richard T. and Bollerslev, Tim, (2000), The forward premium anomaly is not as bad as you think. Journal of International Money and Finance, vol 19, issue 4, pp. 471-488.

Baillie, Richard T. and Kiliç , Rehim, (2005), Do asymmetric and nonlinear adjustments explain the forward premium anomaly? Journal of International Money and Finance, vol 25, issue 1, pp. 22-47.

Bollerslev, Tim (1986), Generalized Autoregressive Conditional Heteroskedasticity. Journal of Econometrics, vol 31, issue 3, pp. 307-328.

Chaboud, Alain P. and Wright, Jonathan H., (2003), Uncovered Interest Rate Parity: It Works, But Not For Long. Journal of International Economics, vol 66, issue 2, pp. 349-362.

Chinn, Menzie D. and Meredith, Guy., (1999), Long-horizon Uncovered Interest Parity. IMF Staff Papers, vol 51, issue 3, pp. 409-430.

Engel, C., (1996), The forward discount anomaly and the risk premium: a survey of recent evidence. Journal of Empirical Finance, vol 3, issue 2, pp. 123-192.

Fama E.F., (1984), Forward and spot exchange rates. Journal of Monetary Economics, vol 14, issue 3, pp. 319-339.

Flood, Robert P. and Rose, Andrew K., (2002), Uncovered interest parity in crisis. IMF Staff Papers, vol 49, issue 2, pp. 252-266.

Froot, Kenneth A. and Thaler, Richard H., (1990), Foreign Exchange, Journal of Economic Perspectives, vol 4, pp. 179-192.

Hodrick, Robert J. and Baillie, Richard T., (1989), The empirical evidence on the efficiency of forward and futures foreign exchange markets. The Economic Journal, vol 99, issue 394, pp. 209-210.

Pilbeam Keath, International Finance, 2nd edition, 1998.

Internet sources

Chinn, M.D. and Meredith, G., Testing uncovered interest parity at short and long horizons during the post Bretton Woods era (2002) http://econ.ucsc.edu/~chinn/uip_empr2002.pdf 2006-01-15

Hodrick Robert J., Srivastana S., An investigation of risk and return in forward foreign exchange (1984) http://www.nber.org/papers/w1180.pdf 2006-03-21

Meredith G. and Ma Y., The forward premium puzzle revisited (2002) http://www.imf.org/external/pubs/ft/wp/2002/wp0228.pdf 2006-03-17

Philip S. Marey, Uncovered interest parity tests and exchange rate expectations (2004) http://gemini.econ.umd.edu/cgi-bin/conference/download.cgi?db_name=SCE2004&paper_id=54

Riksbanken.se http://www.riksbanken.se/templates/stat.aspx?id=16747 and http://www.riksbanken.se/templates/stat.aspx?id=16736 2005-11-10 until 2005-12-01.

Wow Essays, Economic conditions of Japan, http://www.wowessays.com/dbase/ab5/lvt78.shtml 2006-03-22

Appendix

The following four diagrams are comparative graphs for the prediction of the three models and the actual spot exchange rate during the period October 1999 – December 2004.
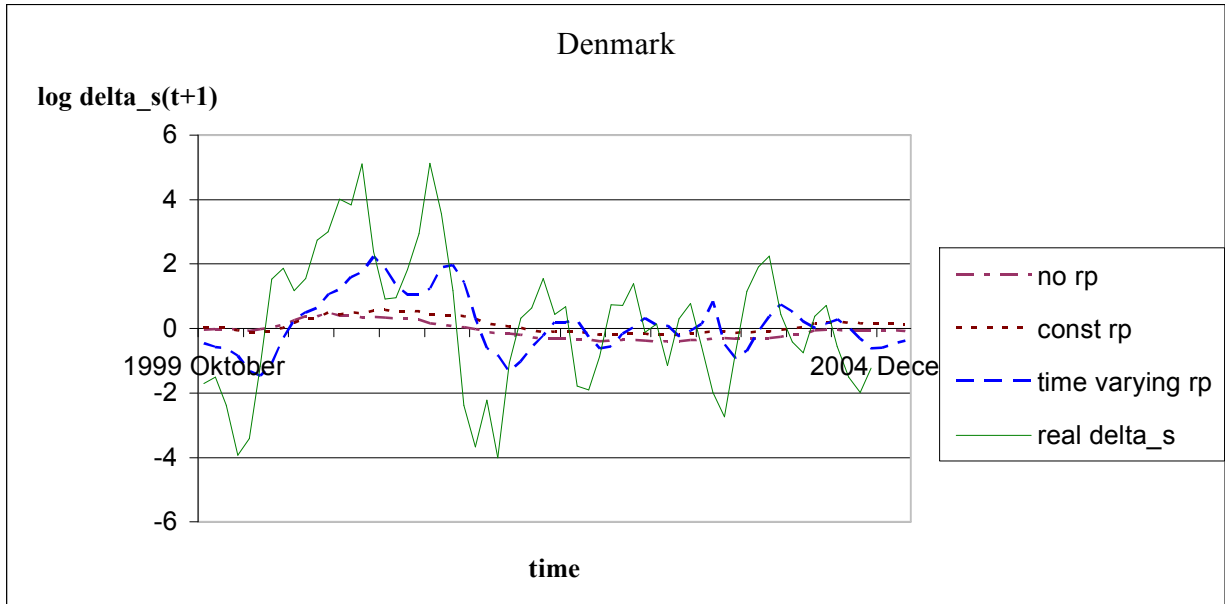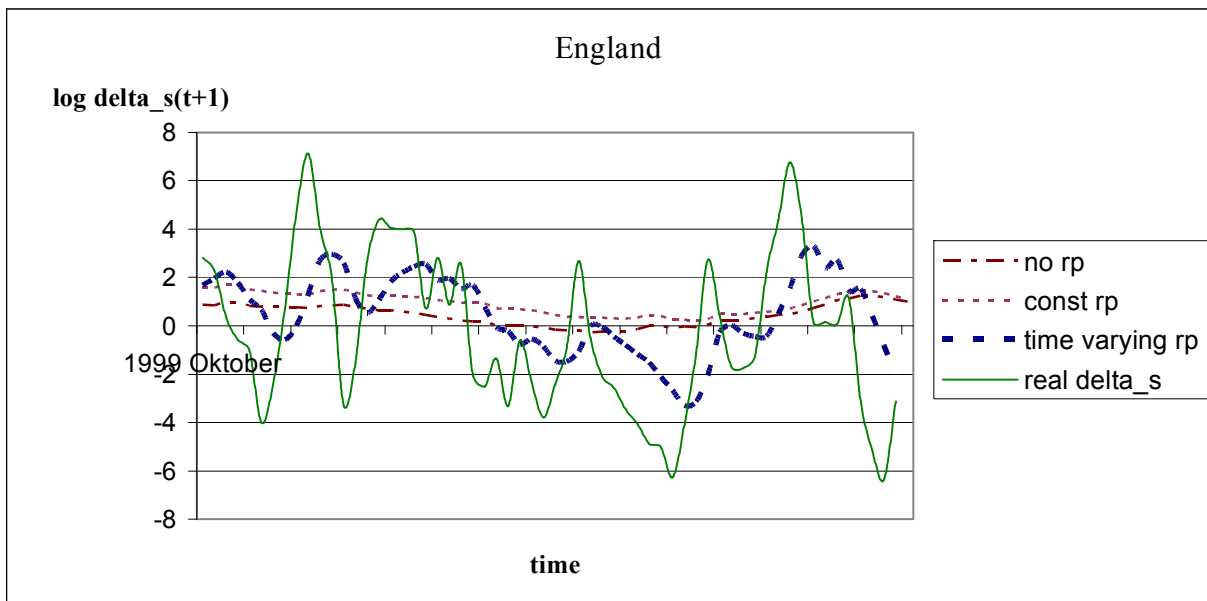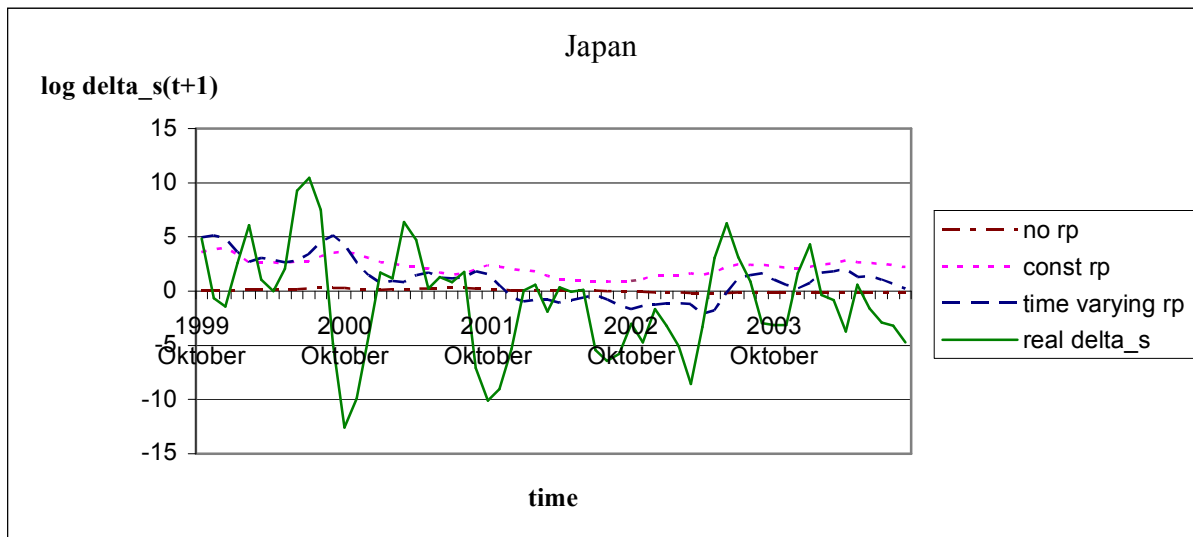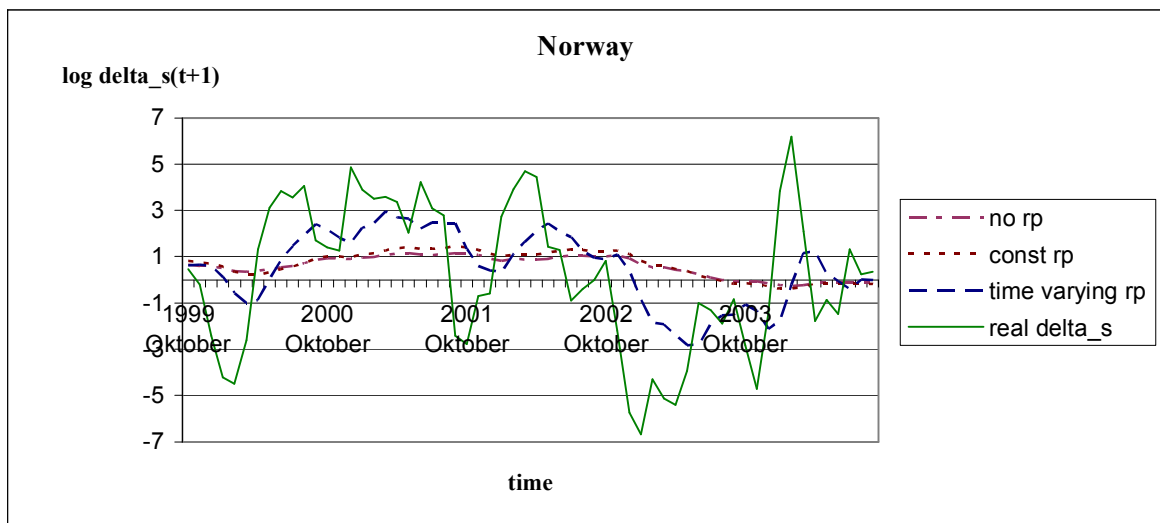

Figure 1

Figure 2

Figure 3

Figure 4

Note: The model without a risk premium and the model with a constant risk premium follow more or less the same pattern for the currencies above. Both of them have a considerable distance to the real exchange rate curve. The model with time varying risk premium though, follows the pattern for the real exchange rate more accurately, although at times at a somewhat large distance. Especially for the predictions with model three for the exchange rate between the Swedish and the Danish krone and between the Swedish krona and the Great Britain pound one can note that the expected exchange rate is a distributed lag of the observed exchange rate, what is known as distributed lag expectations. The spot rate between the Swedish krona and the Japanese yen is the one that has varied the most of the four during this time period.