Risk and uncertainty in the foreign exchange market

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Abstract
In this paper we investigate how volatility and uncertainty affect the foreign exchange market. First we present a theoretical framework to show how volatility and uncertainty affect risk and risk premia in the foreign exchange market. Based on this framework, we use different measures of risk and risk premia to empirically examine the relation between risk, expected volatility and uncertainty of foreign exchange returns. We find that expected volatility and uncertainty have a significant positive effect on implied volatility, the volatility risk premium and the expected return risk premium. We find that volatility of and uncertainty about short term interest rates are the main drivers of this relationship, as well as disagreement on several other exchange-related fundamentals. In light of the ongoing discussion whether or not to treat the foreign exchange market as an asset market, our findings indicate that the foreign exchange market has some properties in common with other asset markets, but that macro-economic fundamentals also matter.

Keywords:
[foreign exchange market risk, disagreement, expectations, forward premium puzzle, survey data]

JEL classification codes: G12, G15

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1. Introduction

In this paper we consider the effect of heterogeneity of beliefs on risk and risk premia in the foreign exchange market. The heterogeneous nature of agents in economic and financial markets is becoming increasingly embedded in the finance literature. This is not only the case for the literature on behavioral finance, also traditional models based on rational expectations have been extended and adjusted to account for heterogeneity among agents. This is often done by modeling a representative agent, while taking into account the disagreement between different market participants (i.e. dispersion of beliefs). Support for such an approach comes from different sources. Fama and French (2007) conclude that disagreement matters for asset pricing if investors are risk averse. If informed traders would be risk neutral, they would offset the positions of the uninformed traders and CAPM prices would sustain. Anderson et al. (2005) find that heterogeneity of beliefs matters for asset pricing, and that disagreement about earnings is a risk factor affecting both equity returns and volatility. Buraschi et al. (2011) also consider disagreement in the equity market, but look at the difference in implied volatilities and volatility risk premia between index and individual stock options. Buraschi and Whelan (2012) focus on bond markets and show that bond risk premia and volatility of the term structure are affected by disagreement about macroeconomic fundamentals and future bond prices. Beber et al. (2010) show that disagreement about future currency returns has a large impact on currency risk premiums.

Besides integrating disagreement directly in the asset pricing model, it can also be used as a proxy for the level of uncertainty in the market. Giordani and Soderlind (2006) show that disagreement about the growth rate of consumption increases the equity premium in an Arrow-Debreu economy. Anderson et al. (2009) link a disagreement factor, based on the weighted cross-sectional volatility of equity return forecasts, to excess returns. Particularly, they decompose the equity risk premium into a compensation for risk (approximated by return volatility) and uncertainty (approximated by disagreement). They find that the uncertainty/return trade-off is stronger than the risk/return trade-off.

There is an ongoing discussion whether the foreign exchange market can be seen as an asset market. There are many papers successfully applying asset pricing theory on the foreign exchange market whereas many fundamental models appear to fail; see Meese and Rogoff (1982). Many puzzles in the foreign exchange literature are still largely unexplained. The forward discount puzzle, being one of the most important foreign exchange puzzles, describes the fact that the forward rate is a biased predictor of the future spot rate. This misalignment is often explained as a time-varying risk premium (see Engel 1996, for an

overview of the related literature). Whether we can indeed regard this misalignment as a risk premium or should blame investors' irrational beliefs is ambiguous. Based on forecasts obtained from a survey, Froot and Frankel (1989) conclude that the bias is almost entirely explained by the biased beliefs of investors. However, Cavaglia et al. (1994) find, with a different dataset and methodology, that the forward discount puzzle is a result of both biased beliefs and the occurrence of time-varying risk premia.

Several authors have linked dispersion in believes to the foreign exchange puzzles. Fisher (2006) proposes a model where the foreign exchange forward premium depends on the diversity of prior beliefs about a country's inflation process. Gourinchas and Tornell (2004) propose a solution for both the forward premium puzzle and the delayed overshooting puzzle based on investor's distorted beliefs about interest rates. Besides risk, uncertainty, and time-varying net risk aversion there are other factors affecting and/or explaining the foreign exchange risk premium. Various authors have shown that carry trade, or the sign of the yield differential, is driving the premium (Brunnermeier et al., 2008; Sarno et al., 2012; Lustig et al., 2012). According to, among others, Lustig and Verdelhan (2007) the state of the U.S. economy and U.S. consumption growth are main determinants. A more microstructure approach is offered in a number of papers (Tien, 2002; Klitgaard and Weir, 2004; Wang, 2004) where they consider the risk premium as an insurance premium. Hedgers participate in the currency futures market to reduce risk of currency movements, whereas speculators participate to gain from currency movements. Therefore, hedgers are willing to pay speculators a risk premium to share their currency exposure risk. Finally, Engel and West (2005) argue that fundamentals matter as an explanation for currency risk prima.

In this paper, we combine literature on exchange rates, equity returns and uncertainty to see how risk and risk premia in the foreign exchange market are related to (expected) volatility and uncertainty. Expected volatility is measured by rolling historical volatility with matching window, and uncertainty is measured as disagreement among investors. We relate these variables to the expected return risk premium - defined as the expected return in excess of the forward premium, implied volatility, and the volatility risk premium - which is a measure of risk aversion. In this way we investigate both the risk premium itself and its components – risk and risk aversion. We find that all three measures are positively related to volatility and uncertainty, and that uncertainty is more important for the risk aversion of investors than volatility. After investigating the sources of this relation, we discover that risk in foreign exchange markets is correlated with volatility and uncertainty of future interest rates. Moreover, uncertainty about certain macro fundamentals such as the future current

account balance and GDP are also very important in explaining risk in the foreign exchange market. This is supportive evidence for the literature trying to link exchange rate movements with fundamentals.

This paper contributes to the current literature in various ways. First of all, we adopt a framework from the literature on equity returns and inflation expectations and apply it to the foreign exchange market. Our results show that this asset market approach for the foreign exchange market is successful. Moreover, we demonstrate that even though the FX market has certain features in common with other asset markets, trade-related fundamentals also matter for the foreign exchange risk premium. In addition we have a direct and straightforward way for measuring the expected return risk premium, using survey forecasts proxying for investors' expected return. This enables us to investigate the expected return risk premium without making strict assumptions about investors' rationality.

The remaining of the paper is set up as follows. Section 2 describes the model that links risk premia in the foreign exchange market to expected volatility and uncertainty. It also discusses the method of estimation and our datasets. Section 3 covers the results from estimating the model from section 2. Based on these findings, we estimate the model using volatility and uncertainty of fundamentals and present the results in the remainder of Section 3. Section 4 summarizes the results and discusses implications for current and future research.

2. Model and Methodology

2.1 Expected return risk premium

Let us consider an investor borrowing in a country where interest rates are low and investing in a country where interest rates are high. The log returns of such an investor can be decomposed in returns from the interest differential and returns on the exchange rate movement[2]:

$$E[r_{t+1}] = E[\Delta s_{t+1}] + \left(i^{high} - i^{low}\right) \quad (1)$$

[2] At the end of the period, the investor needs to pay his loan back in the low yielding currency and therefore benefits from an appreciation of the high yielding currency.

Where i^{high} is the interest rate of the high yielding currency and i^{low} is the interest rate of the low yielding currency. E[Δs_{t+1}] is the expected change in exchange rate denoted as the low yielding currency over the high yielding currency.

According to the interest parity relations the interest differential between the countries should be offset by a change in the exchange rate in the opposite direction. Even though there is little evidence for uncovered interest parity (UIP) to hold, we can assume covered interest parity (CIP) to hold as this is an arbitrage relation.

$$f_t - s_t = i^{home} - i^{U.S.} \tag{2}$$

Combining (1) and (2) gives us the following excess return relation:

$$E[r_{t+1}] = E[\Delta s_{t+1}] - fd_t \tag{3}$$

where fd_t is the forward discount. If UIP holds $E[\Delta s_{t+1}] = fd_t$ and there would be no returns to be realized. However, there is ample evidence in the literature that the latter relation does not hold, often referred to as the forward premium bias or the forward discount bias (a summary of the relevant literature can be found in Engel, 1996).

One of the explanations for this puzzle is that international investors demand a premium for the risk they bare that the exchange rate moves against them. This is typically referred to as a time-varying risk-premium distorting the relation:

$$E[s_{t+1} - s_t] = i^{home} - i^{U.S.} + \rho_t \tag{4}$$

where ρ is the risk premium. The magnitude of the risk premium depends on two factors: the risk and the risk aversion of the investor:

$$\rho_t = risk_t \times \gamma_t \tag{5}$$

Combining equations (3)-(5) tells us that the return r_{t+1} of the investor should equal the time-varying risk premium ρ_t. In other words, the return of the investor is a compensation for the risk of (unexpected) future exchange rate movements, scaled by her or his risk aversion:

$$E[r_{t+1}] = E[\Delta s_{t+1}] - fd_t = risk_t \times \gamma_t \quad (6)$$

2.2 Volatility and uncertainty

Anderson et al. (2009) relate the equity risk premium, defined as excess returns on the equity market to a decomposition of risk in volatility and uncertainty. They argue that investors want to be compensated for known and unknown 'unknowns'. Applying this relation to the foreign exchange market gives:

$$\rho_t = risk_t \times \gamma_t = F\{\sigma_t, \psi_t\} \quad (7)$$

The foreign exchange risk premium, decomposed into risk and risk aversion, is a function of volatility σ_t of and disagreement ψ_t on future exchange rate returns.

We can directly link risk and risk aversion to volatility and uncertainty by following the approach of Giordani and Soderlind (2003). They argue that the variance of the aggregate distribution, of expected inflation in their case[3], is composed out of the average individual expected volatility and disagreement among investors. Translating this relation to the foreign exchange market gives:

$$Var(\Delta s_t) = E\left(\sigma^2_{\Delta s_t}\right) + Var(E[\Delta s_t]) \quad (8)$$

Putting it differently, the total risk of the market is a sum of the individual expected volatility and the dispersion in expected returns.

Empirically, we proxy total market risk by the implied volatility of currency options, σ^2_{IV}. Expected individual volatility is defined as historical volatility, σ^2 and uncertainty is measured by investor disagreement, $Var(\mu_i)$. Rewriting and replacing then gives us:

$$\sigma^2_{IV} = \sigma^2 + Var(\mu_i) \quad (10)$$

Such that

[3] Huisman et al. (2012) apply a similar approach to the equity market.

$$\sigma_{IV}^2 - \sigma^2 = Var(\mu_i) \tag{11}$$

where $\sigma_{IV}^2 - \sigma^2$ is generally considered to be the volatility risk premium (Bollerslev et al., 2011).

In the remainder of the paper, we study the relations given by (7) to (11) empirically in order to determine the relative importance of volatility and uncertainty for different risk measures in the foreign exchange market. To be more specific, we estimate the following three regressions. First the relation between implied volatility and total risk, given by (10):

$$\sigma_{IV}^2 = \alpha + \beta\sigma^2 + \gamma Var(\mu_i) + \varepsilon \tag{12a}$$

Second, we study the expected return risk premium, based on survey data of exchange rate expectations. That is,

$$E[\Delta s_{t+1}] - f_t = \alpha + \beta\sigma^2 + \gamma Var(\mu_i) + \varepsilon \tag{12b}$$

Third, we examine the volatility risk premium

$$\sigma_{IV}^2 - \sigma = \alpha + \beta\sigma^2 + \gamma Var(\mu_i) + \varepsilon \tag{12c}$$

3. Data & Method

3.1 Expectations and uncertainty

For a long time, expected returns were proxied by ex-post realized returns based on the rational expectations framework, as actual expectations were not observable. This partly changed in and after the eighties when companies like Money Market Services International (MMSI) and Consensus Economics started to gather investors' expectations of future asset prices by means of surveys. Dominguez (1986) and many others after her found based on the survey results that investor expectations and realized outcomes are seriously misaligned, both on individual and aggregated level. When considering expected return risk premia, we therefore choose to work with survey forecasts as a close proxy for expectations instead of using realized returns in combination with a number of strict assumptions.

Furthermore, Giordani and Soderlind (2003) found that individuals underestimate total risk (i.e. have too narrow confidence intervals around their point forecasts), which is

confirmed by Huisman et al. (2010), who find that investors only take their own risk into account, while the total market risk is larger because of differences in point forecasts. Therefore Giordani and Soderlind (2003) consider disagreement to be a better proxy for market uncertainty. Although Bomberger (1996) claims that disagreement is smaller than individual uncertainty rather than larger, he finds that the relation is linear and stable, and therefore concludes disagreement is still a good proxy for uncertainty. When using disagreement as a measure of uncertainty, we assume that the forecasters only disagree on the point forecasts, and not on higher moments.

3.2 Data

For the first part of this paper, we use a dataset with monthly forecasts from financial analysts and investors gathered by Consensus Economics®. Consensus Economics is the world's leading international economic survey organization and their datasets are unique in terms of their long time span, large number of respondents, level of responding institutions, and the disaggregate level of forecasts. Forecasts are given every month for the future value of the dollar against the Euro and the Japanese yen 1, 3 and 12 months ahead. Our sample runs from January 1999 to December 2009. Besides the survey data we use implied volatilities, and spot and forward exchange rates from Thomson Reuters (obtained through Datastream).

3.3 Descriptive statistics

< Insert tables 1.1-1.4 about here >

Descriptive statistics for the variables of interest are shown in Tables 1.1-1.4. We can see that the longer the horizon, the larger the disagreement is on future values of the exchange rates. The same goes for annualized historical volatility. The expected (log) return risk premium is on average negative for the Euro and positive for the Japanese yen.

4. Results

4.1 FX Market

In this section we discuss the empirical analysis as a result of the theoretical implications from previous sections. Our empirical analysis consists of linear regressions to estimate the

relation between different features of foreign exchange risk premia on the one hand and volatility and uncertainty on the other hand.

Whereas implied volatility is a measure of risk and the return risk premium is a complete measure for the demanded risk compensation, as a combination of risk and risk aversion, the volatility risk premium reveals the level of risk aversion. Analyzing all three of them gives a complete image of the relation between volatility and uncertainty and those three features of the foreign exchange market.

4.1.1 Implied volatility

The implied volatility of an asset is the risk-neutral volatility implied from an option pricing model such as the Black and Scholes (1973) model. Due to the fact that investors in real life are risk averse, realized volatility is generally smaller than implied volatility. Therefore, implied volatility can be seen as a purer and more direct measure of the true risk in the market. To see how this measure of risk relates to expected volatility (proxied by realized historical volatility) and uncertainty, we regress implied volatility on historical volatility of the exchange rate and disagreement about future values of the exchange rate.

< Insert Table 2 about here >

Table 2 shows the results of this regression for the Euro against the US dollar and the Japanese yen against the US dollar. We can see that historical volatility is positively correlated with implied volatility, as expected. More interestingly, uncertainty, measured by disagreement, has a large and significant effect on implied volatility beyond the impact of historical volatility. Moreover, adjusted R-squareds from this regression are all between 0.421 and 0.738, which means that the combination of volatility and uncertainty explains a large part of the variance of implied volatility.

4.1.2 Expected return risk premium

The difference between the expected exchange rate and the forward rate is the risk premium investors demand to be compensated for the volatility of currency returns and the uncertainty about the return process.

< Insert Table 3 about here >

Looking at the results in Table 3 we can see that it is mainly uncertainty that investors want to be compensated for. For both currencies and all horizons our disagreement variable has a statistically significant effect (on 1% or 5%) on the expected return risk premium. The impact of volatility on expected return risk premia is ambiguous. For the Euro it only has a significant impact for the 12 months horizon, and this effect is negative, implying that when Euro returns are more volatile, investors demand a lower return risk premium. Volatility has a statistically significant positive effect on the expected risk premium for the Japanese yen for the 1 month and 12 month horizon, but this effect is very small. With the exception of the 1 month horizon for the Euro, adjusted R-squares are around 0.15 to 0.35.

4.1.3 Volatility risk premium

Besides facing the risk of volatile and uncertain returns, investors also face the risk of volatile volatility. The compensation for this is measured by the volatility risk premium, which is the difference between the implied volatility of a currency and its realized volatility. Because risk-averse investors accept lower returns if volatility is lower, risk-neutral implied volatility is higher than realized volatility if investors are indeed risk averse. Therefore, the volatility risk premium is also a measure of risk aversion.

< Insert Table 4 about here >

Table 4 displays the results of regressing the volatility risk premium on volatility and uncertainty. The volatility risk premium of the Euro is affected by both volatility and uncertainty, whereas the volatility risk premium of the Japanese yen is only affected by uncertainty. Except for the 1 month horizon of the Euro these results are all statistically significant at the 1% level. These results imply that risk aversion is mainly affected by uncertainty about future currency returns.

4.2 Sources of risk and uncertainty: interest rates and fundamentals

Now we know that risk and risk premia are affected by volatility of and uncertainty about future currency returns, it is interesting to see what the source of this relation is. There are two related ongoing debates that should be considered here. The first one is the debate about whether the foreign exchange market should be considered as an asset market, responding mainly to financial and monetary fundamentals such as interest rates, or as a market that is mainly influenced by trade flows and therefore responds to real and nominal fundamentals

such as GDP, inflation and current account balance. In the second debate it is questioned whether currency returns are related to fundamentals at all.

Looking at the underlying sources of currency risk and returns, the risk investors in the foreign exchange market face (and want to be compensated for) can be decomposed in three parts:

1. The volatility of the underlying fundamentals
2. The uncertainty in the market about the movement of the underlying fundamentals
3. The uncertainty about the impact of the underlying fundamental model on the exchange rate

$$risk_t = \alpha + \lambda\sigma_t + \delta\psi_t + \varepsilon_t \tag{13}$$

The uncertainty about the impact of the underlying fundamental model on exchange rate movement is assumed to be time-invariant (α). Therefore, the time-variation in the currency risk comes from the time-varying volatility of the fundamental (σ_t) and the market uncertainty about future movements of the fundamental (ψ_t).

For this second part of the paper we use a different dataset with survey forecasts for macro fundamentals. The forecasts we use to construct a measure for uncertainty are budget balance, current account, GDP, investments, industrial production, 3 month interest rates and 10 year government yields. The survey also contains consensus forecasts for the dollar against the Australian dollar, Japanese yen and New Zealand dollar. The exchange rate forecasts and interest rate forecasts are given monthly for horizons of 3 and 12 months. Forecasts on the other fundamentals are for realizations of those fundamentals for the current year. Therefore we cannot directly compare it to the analysis for the Euro and Japanese yen from the previous section. This also means that our uncertainty measure is only based on disagreement on future Australian, Japanese and New Zealand interest rates, and excludes disagreement on future U.S. interest rates.

4.2.1 Interest rates

Using the uncovered interest parity from equation (5) as underlying model, the relevant fundamental factor investors are concerned about is the interest rate differential ($i^{home} - i^{U.S.}$). Lustig et al. (2008) also stress the importance of interest rates for risk premia in the foreign exchange market. They show that currency risk premia are mainly determined by a

global risk factor measured by interest rate differentials. We therefore consider the effect of interest rate volatility and uncertainty on risk and risk premia, to see whether we find similar effects as in the previous section.

Implied volatility

< Insert tables 5.1-5.3 about here >

The results of regressing implied volatility of exchange rates on uncertainty and volatility of the foreign (Australian, Japanese, or New Zealand) interest rates are presented in tables 5.5-5.3. At first sight it seems as if uncertainty and volatility of foreign interest rates have a significant impact on implied volatility. However, after controlling for U.S. interest rate volatility and the volatility of the exchange rate itself, most of these effects disappear. Therefore the results may be driven by correlation with these variables. Unfortunately we do not have matching data on uncertainty of the exchange rates for this sample.

Expected return risk premium

< Insert tables 6.1-6.3 about here >

As we can see from the results in tables 6.1-6.3 the expected return risk premium cannot be explained by volatility of and uncertainty on interest rates. This is in line with previous research, where a stable and linear relation between (excess) returns and interest rates seems to be absent (e.g. Meese and Rogoff, 1988; Bacchetta and Van Wincoop, 2009; Sarno and Valente, 2008).

Volatility risk premium

< Insert table 7.1-7.3 about here >

Tables 7.1-7.3 present the results of regressing the volatility risk premium on uncertainty and volatility of the foreign interest rates. Volatility and uncertainty both seem to be related to the volatility risk premium. However, when we control for the volatility of the U.S. interest rate and the volatility of the exchange rate, only the effect of the interest rate volatility seems to

persist. This implies that risk aversion in the foreign exchange market is related to the volatility of interest rates.

4.2.2 Fundamentals

Many attempts have been made to connect exchange rate movements to (macro)fundamentals (the first and most famous example being Meese and Rogoff, 1983), and many have failed. Exchange rate movements, especially for horizon of a year or less, do not seem to be related to movements of (macro)fundamentals. In this section we will investigate whether this is different for aspects of risk. We therefore relate implied volatility, expected return risk premium, and volatility risk premium to uncertainty on a number of fundamentals, such as current account balance and GDP.

Implied volatility

< Insert table 8.1-8.3 about here >

Uncertainty about the current account balance is statistically significant and positively related to currency risk. Uncertainty about the real economy matters as well, GDP is an important measure for Australia and New Zealand, whereas industrial production matters for Japan. The implied volatility of the NZ dollar is also affected by uncertainty about New Zealand's budget balance. Uncertainty about interest rates affects the riskiness of all three currencies. Uncertainty about investments is not related to exchange rate risk.

Expected return risk premium

< Insert table 9.1-9.3 about here >

In tables 9.1-9.3 we can see that uncertainty about trade and the real economy take over the significance from interest rate uncertainty. This indicated that for the expected risk premium, real factors seem to be more important than monetary or financial factors.

Volatility risk premium

< Insert table 10.1-10.3 about here >

As seen from Tables 10.1-10.3, the volatility risk premium is related to uncertainty on the current account for Australia and New Zealand, and this effect is not subsumed by the significant effect of interest rate uncertainty. For the volatility risk premium of the New Zealand dollar, budget balance uncertainty is also a driving factor. Interest rate uncertainty is persistently important for the Japanese yen, as well as uncertainty concerning industrial production.

In general we find that risk in the foreign exchange market is related to certain trade-related fundamentals through uncertainty about these fundamentals.

5. Conclusion

In this paper we have investigated the relation between foreign exchange market risk and volatility and uncertainty of exchange rates and fundamentals. Different features of foreign exchange market risk have been considered – return risk premium, risk and volatility risk premium (also a poxy for risk aversion). Return risk premium was measured as the difference between the expected return of the currency and the forward premium, risk was proxied by implied volatility and the volatility risk premium was calculated as the difference between implied and realized volatility. We have found that volatility and uncertainty are both related to foreign exchange risk, but that investors mainly want to be compensated for uncertainty.

Results of further investigating the sources of this relationship indicate that uncertainty on exchange-related fundamentals explain a large part in the variation of foreign exchange risk and risk premia. Volatility of and uncertainty on interest rates seem to have an effect on exchange rate risk, but this effect largely disappears after controlling for exchange rate volatility. It turns out that uncertainty on certain real factors, such as current account balance and GDP are more important. This is supportive evidence for the literature trying to link exchange rate movements with fundamentals.

This paper contributes to the current literature in various ways. First of all, we adopt a framework from the literature on equity returns and inflation expectations and apply it to the foreign exchange market. Our results show that this asset market approach for the foreign exchange market is successful. Moreover, we demonstrate that even though the FX market

has certain features in common with other asset markets, trade-related fundamentals also matter for the foreign exchange risk premium. In addition we have a very direct and straightforward way for measuring the expected return risk premium, viz using survey forecasts proxying for investors' expected return. This enables us to investigate the expected return risk premium without making strict assumptions about investors' rationality.

Future research is necessary to further investigate the relation between risk and uncertainty of fundamentals and risk of foreign exchange movements, to isolate the fundamentals that are most important and identify which fundamentals drive what currency returns and why.

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Tables

Table 1.1-1.4 – Descriptive statistics

Disagreement

	Euro			Japan		
	1m	3m	12m	1m	3m	12m
Mean	0.028	0.040	0.068	2.842	4.238	7.243
Median	0.026	0.039	0.067	2.700	4.000	6.950
Maximum	0.170	0.076	0.103	7.400	10.300	13.600
Minimum	0.014	0.023	0.037	1.600	2.700	4.700
Std. Dev.	0.014	0.011	0.014	0.887	1.138	1.653

Table 1.1

Historical volatility

	Euro			Japan		
	1m	3m	12m	1m	3m	12m
Mean	0.043	0.129	0.527	6.219	18.038	74.855
Median	0.037	0.114	0.493	5.734	15.640	74.049
Maximum	0.144	0.350	0.989	26.520	85.014	176.936
Minimum	0.009	0.038	0.145	1.839	6.520	29.674
Std. Dev.	0.023	0.067	0.209	3.295	9.902	32.625

Table 1.2

Implied Volatility

	Euro			Japan		
	1m	3m	12m	1m	3m	12m
Mean	10.428	10.502	10.628	11.235	11.150	11.171
Median	9.963	10.213	10.400	10.300	10.113	10.600
Maximum	21.750	20.255	18.200	24.500	21.500	18.600
Minimum	5.050	5.250	5.630	6.275	6.600	6.650
Std. Dev.	2.917	2.682	2.369	3.493	3.066	2.749

Table 1.3

Expected return RP

	Euro			Japan		
	1m	3m	12m	1m	3m	12m
Mean	-0.006	-0.010	-0.022	0.002	0.006	0.020
Median	-0.004	-0.010	-0.018	0.001	0.005	0.021
Maximum	0.031	0.036	0.074	0.086	0.114	0.171
Minimum	-0.064	-0.075	-0.158	-0.057	-0.068	-0.080
Std. Dev.	0.018	0.021	0.040	0.019	0.027	0.044
Skewness	-0.691	-0.313	-0.467	0.740	0.454	0.273

Table 1.4

Table 2 - FX Implied volatility

	Europe						Japan					
IV	1m		3m		12m		1m		3m		12m	
constant	5,576	***	2,314	***	3,485	***	2,670	***	2,624	***	2,985	***
	4,465		2,678		2,449		3,604		3,465		4,695	
FX unc	56,686		135,550	***	55,534	***	2,526	***	1,865	***	0,918	***
	1,044		7,894		2,924		9,229		10,252		7,713	
FX exp vol	70,572	***	20,407	***	6,092	***	0,223	***	0,035		0,020	**
	5,453		8,845		3,782		3,557		1,303		2,297	
adj R2	0,421		0,738		0,491		0,617		0,586		0,547	

The table above shows the results from regressing the implied volatility of the EUR/USD and JPY/USD exchange rates on the expected volatility of currency returns, proxied by historical volatility, and uncertainty about future exchange rate returns, proxied by disagreement. Significance of the coefficients is denoted by *, **, or *** for levels of 10%, 5%, or 1%. Shaded numbers are t-statistics.

Table 3 – FX Expected return risk premium

	Europe						Japan					
Exp return RP	1m		3m		12m		1m		3m		12m	
constant	-0,012	***	-0,031	***	-0,040	*	-0,024	***	-0,054	***	-0,071	***
	-2,339		-4,678		-1,840		-4,459		-5,887		-3,992	
FX unc	0,155	**	0,787	***	0,894	***	0,005	***	0,014	***	0,008	***
	2,019		5,181		2,797		2,405		5,461		2,648	
FX exp vol	0,057		-0,080	***	-0,080	***	0,002	***	0,000		0,000	***
	0,695		-2,656		-3,009		3,134		0,419		3,036	
adjR2	0,010		0,148		0,199		0,237		0,351		0,328	

The table above shows the results from regressing the expected return risk premium of the EUR/USD and JPY/USD exchange rates on the expected volatility of currency returns, proxied by historical volatility, and uncertainty about future exchange rate returns, proxied by disagreement. Significance of the coefficients is denoted by *, **, or *** for levels of 10%, 5%, or 1%. Shaded numbers are t-statistics.

Table 4 – FX Volatility Risk Premium

	Europe						Japan					
VRP	1m		3m		12m		1m		3m		12m	
constant	5,678	***	3,188	***	4,161	***	4,280	***	3,889	***	3,639	***
	6,585		5,204		3,567		5,566		5,907		5,926	
FX unc	40,764		101,609	***	35,402	***	1,781	***	1,420	***	0,743	***
	1,038		8,716		2,330		7,013		8,542		7,518	
FX exp vol	54,602	***	16,044	***	5,381	***	0,096		-0,002		0,011	
	5,535		8,464		4,019		1,340		-0,082		1,377	
adj R2	0,412		0,714		0,455		0,463		0,476		0,483	

The table above shows the results from regressing the volatility risk premium of the EUR/USD and JPY/USD exchange rates on the expected volatility of currency returns, proxied by historical volatility, and uncertainty about future exchange rate returns, proxied by disagreement. Significance of the coefficients is denoted by *, **, or *** for levels of 10%, 5%, or 1%. Shaded numbers are t-statistics.

Table 5.1-5.3 – Interest rates: Implied volatility

	Australia											
IV	3m						12m					
	I		II		III		I		II		III	
constant	8,839	***	8,530	***	4,508	***	11,924	***	11,367	***	4,559	***
	6,437		7,255		7,239		21,806		16,456		5,119	
unc for int rate	5,010		4,330		2,560		-9,427	***	-9,008	***	-0,624	
	0,654		0,661		0,938		-7,085		-6,223		-0,507	
exp vol for int rate	10,957	***	4,577		-3,298	*	6,944	***	5,929	***	-1,259	
	2,573		1,145		-1,657		6,502		4,769		-1,247	
exp vol U.S. int rate			9,572	***	-0,222				1,935	*	0,144	
			2,825		-0,151				1,791		0,265	
FX exp vol					56,915	***					58,893	***
					10,894						8,391	
adj R2	0,196		0,305		0,800		0,366		0,392		0,812	

Table 5.1

	Japan											
IV	3m						12m					
	I		II		III		I		II		III	
constant	9,204	***	8,637	***	3,592	***	10,141	***	10,006	***	5,163	***
	24,146		7,255		7,358		22,535		14,075		6,998	
unc for int rate	14,080	***	13,107		4,751		2,787		2,919		1,391	
	2,587		0,661		1,615		1,423		1,459		1,067	
exp vol for int rate	18,037	***	17,187		3,961		6,664	***	6,606	***	3,961	***
	3,660		1,145		1,219		4,187		4,168		2,632	
exp vol U.S. int rate			5,291	***	0,431				0,290		-0,273	
			2,825		0,501				0,303		-0,473	
FX exp vol					64,587	***					51,810	***
					13,316						8,568	
adj R2	0,243		0,317		0,734		0,132		0,129		0,581	

Table 5.2

	New Zealand											
IV	3m						12m					
	I		II		III		I		II		III	
constant	9,811	***	9,740	***	3,957	***	8,990	***	8,673	***	3,161	***
	11,585		11,955		7,297		10,328		10,864		3,360	
unc for int rate	9,263	*	7,487		3,702		4,575	*	3,701		-0,460	
	1,882		1,500		1,556		1,887		1,513		-0,382	
exp vol for int rate	11,022	***	8,175	***	-3,288	*	4,449	***	3,985	***	-1,314	**
	4,489		2,631		-1,682		7,069		5,685		-2,040	
exp vol U.S. int rate			5,169	**	0,708				1,806	**	0,153	
			2,250		0,577				2,132		0,392	
FX exp vol					67,475	***					79,370	***
					12,068						79,370	
adj R2	0,373		0,415		0,783		0,475		0,506		0,828	

Table 5.3

The tables above show the results from regressing the implied volatility of the AUD/USD, the JPY/USD and NZD/USD exchange rates on the expected volatility of interest rates,

proxied by historical volatility, and uncertainty about future foreign interest rates, proxied by disagreement. Model III controls for the historical volatility of the exchange rate.
Significance of the coefficients is denoted by *, **, or *** for levels of 10%, 5%, or 1%.
Shaded numbers are t-statistics.

Table 6.1-6.3 – Interest rates: Expected return risk premium

	Australia											
Exp return RP	3m						12m					
	I		II		III		I		II		III	
constant	-0,016	***	-0,017	***	-0,023	***	-0,040	***	-0,035	***	-0,041	*
	-2,989		-3,127		-3,133		-2,893		-2,440		-1,774	
unc for int rate	0,025		0,023		0,029		0,011		0,008		0,015	
	1,107		1,029		1,194		0,466		0,340		0,451	
exp vol for int rate	0,022		0,014		0,010		0,004		0,012		0,009	
	1,015		0,787		0,618		0,287		0,774		0,468	
exp vol U.S. int rate			-0,015		-0,005				-0,018		-0,019	
			-0,916		-0,255				-0,724		-0,764	
FX exp vol					0,061						0,047	
					1,131						0,484	
adj R2	0,024		0,026		0,036		-0,001		0,006		0,004	

Table 6.1

	Japan											
Exp return RP	3m						12m					
	I		II		III		I		II		III	
constant	0,004		0,003		-0,021	**	0,019	*	0,014		-0,049	***
	0,653		0,572		-2,300		1,772		0,966		-2,870	
unc for int rate	0,037		0,036		0,014		0,038		0,040		0,024	
	0,914		0,894		0,359		0,698		0,736		0,423	
exp vol for int rate	0,012		0,012		0,008		0,013		0,010		0,016	
	0,385		0,367		0,351		0,473		0,355		0,591	
exp vol U.S. int rate			0,003		-0,014				0,011		0,009	
			0,243		-1,069				0,739		0,627	
FX exp vol					0,277	***					0,618	***
					3,487						5,705	
adj R2	0,006		0,002		0,113		0,015		0,016		0,222	

Table 6.2

	New Zealand											
Exp return RP	3m						12m					
	I		II		III		I		II		III	
constant	-0,004		-0,003		-0,014		-0,035		-0,030		-0,072	***
	-0,612		-0,384		-1,414		-1,500		-1,261		-2,382	
unc for int rate	-0,042	**	-0,045	**	-0,034		0,012		0,011		0,045	
	-2,111		-2,016		-1,513		0,359		0,315		1,150	
exp vol for int rate	0,055	***	0,058	***	0,048		0,001		0,002		-0,012	
	3,555		3,144		2,561		0,058		0,134		-0,703	
exp vol U.S. int rate			-0,009		-0,023				-0,011		-0,031	
			-0,420		-0,860				-0,397		-1,072	
FX exp vol					0,099						0,360	**
					1,078						2,129	
adj R2	0,055		0,052		0,064		-0,009		-0,011		0,026	

Table 6.3

The tables above show the results from regressing the expected return risk premium of the AUD/USD, the JPY/USD and NZD/USD exchange rates on the expected volatility of interest rates, proxied by historical volatility, and uncertainty about future foreign interest rates, proxied by disagreement. Model III controls for the historical volatility of the exchange rate. Significance of the coefficients is denoted by *, **, or *** for levels of 10%, 5%, or 1%. Shaded numbers are t-statistics.

Table 7.1-7.3 – Interest rates: Volatility risk premium

	Australia											
VRP	3m					12m						
	I		II		III		I		II		III	
constant	9,333	***	0,626		8,100	***	10,389	***	0,626	***	7,126	***
	14,023		0,861		7,007		22,834		-3,015		7,268	
unc for int rate	2,420		-3,482		1,765		-4,570	***	-3,482	***	-0,721	
	0,532		-0,836		0,474		-3,590		-3,861		-0,503	
exp vol for int rate	-2,532		-2,834		-6,140	**	1,590		-2,834	***	-2,124	*
	-0,837		-0,908		-2,188		1,630		-4,065		-1,813	
exp vol U.S. int rate			-2,849		-0,867				-2,849		0,456	
			-1,498		-0,358				-1,042		0,667	
FX exp vol					16,540	*					25,181	***
					1,772						3,326	
adj R2	0,004		0,134		0,108		0,121		0,134		0,345	

Table 7.1

	Japan											
VRP	3m					12m						
	I		II		III		I		II		III	
constant	8,527	***	-0,038		5,245	***	9,031	***	-0,324	***	5,402	***
	28,034		0,861		9,437		25,321		-3,015		8,286	
unc for int rate	9,958	***	0,314		4,503		2,995	*	2,708	***	1,821	
	2,537		-0,836		1,479		1,947		-3,861		1,548	
exp vol for int rate	12,411	***	2,203		4,164		4,667	***	1,814	***	2,682	***
	3,261		-0,908		1,276		3,957		-4,065		2,484	
exp vol U.S. int rate			0,988		0,109				-0,301		-0,471	
			-1,498		0,109				-1,042		-0,979	
FX exp vol					37,950	***					39,053	***
					6,993						7,359	
adj R2	0,207		0,013		0,499		0,122		0,119		0,516	

Table 7.2

	New Zealand											
VRP	3m					12m						
	I		II		III		I		II		III	
constant	9,418	***	0,058		6,372	***	9,013	***	0,097		5,368	***
	16,454		0,155		11,031		13,168		0,228		5,563	
unc for int rate	7,813	***	1,015		4,914	**	2,804		-0,260		-0,387	
	2,457		0,476		2,000		1,560		-0,242		-0,325	
exp vol for int rate	1,875		-3,558	**	-5,579	***	1,835	***	-0,375		-1,780	***
	1,072		-2,276		-2,659		2,794		-0,719		-2,791	
exp vol U.S. int rate			1,389		0,384				0,727	*	0,226	

		1,162	0,273			1,931	0,553		
FX exp vol			35,103	***			49,309	***	
			6,029				5,870		
adj R2	0,127	0,047	0,400		0,217	0,021	0,556		

Table 7.3

The tables above show the results from regressing the volatility risk premium of the AUD/USD, the JPY/USD and NZD/USD exchange rates on the expected volatility of interest rates, proxied by historical volatility, and uncertainty about future foreign interest rates, proxied by disagreement. Model III controls for the historical volatility of the exchange rate. Significance of the coefficients is denoted by *, **, or *** for levels of 10%, 5%, or 1%. Shaded numbers are t-statistics.

Table 8.1-8.3 – Fundamentals: Implied volatility

Australia								
IV	3m				12m			
	I		II		I		II	
constant	10,615	***	9,259	***	10,663	***	10,176	***
	9,779		8,019		11,572		10,973	
BB unc	-0,049		-0,025		0,028		0,037	
	-0,344		-0,183		0,184		0,247	
CA unc	0,791	***	0,723	***	0,737	***	0,754	***
	5,622		6,362		7,421		7,779	
GDP unc	-6,540	***	-6,590	***	-5,635	***	-5,260	***
	-2,369		-2,740		-3,024		-2,776	
Inv unc	0,078		0,011		-0,149		-0,182	
	0,231		0,034		-0,593		-0,787	
IP unc	-0,518		-0,230		-0,618		-0,697	
	-0,869		-0,478		-1,192		-1,371	
unc for int rate			11,822	*			-3,066	**
			1,751				-2,061	
unc for gtv yield			-3,153				4,126	
			-0,910				1,632	
adj R2	0,473		0,507		0,551		0,561	

Table 8.1

Japan								
IV	3m				12m			
	I		II		I		II	
constant	9,352	***	6,186	***	9,168	***	7,043	***
	7,677		4,191		9,609		5,257	
BB unc	0,075		0,121		0,137		0,158	
	0,488		0,885		1,205		1,443	
CA unc	0,119		0,082		0,140	*	0,046	
	1,265		1,017		1,800		0,648	
GDP unc	1,922		-2,473		2,611		-0,790	
	0,824		-1,045		1,258		-0,350	
Inv unc	-0,513		-0,016		-0,695		-0,248	
	-0,963		-0,035		-1,452		-0,492	
IP unc	1,004	***	1,327	***	0,827	**	1,335	***
	2,685		3,590		2,098		3,619	
unc for int rate			15,879	***			5,301	**
			2,733				2,105	
unc for gtv yield			11,672	***			4,490	
			2,667				1,408	
adj R2	0,102		0,263		0,130		0,194	

Table 8.2

New Zealand								
IV	3m				12m			
	I		II		I		II	
constant	8,866	***	6,389	***	8,560	***	6,767	***
	7,948		4,762		9,501		4,928	
BB unc	3,169	***	3,077	***	2,658	***	2,391	***
	4,274		4,626		4,933		5,032	
CA unc	0,569	**	0,500		0,954	***	0,985	***
	2,043		1,328		4,267		4,541	
GDP unc	2,260		0,579		0,638		-0,715	
	1,048		0,270		0,380		-0,397	
Inv unc	0,420		0,123		0,493		0,353	
	1,145		0,305		1,581		1,406	
IP unc	-0,758		-0,488		-0,311		-0,296	
	-1,353		-1,180		-0,631		-0,599	
unc for int rate			13,867	***			0,692	
			2,626				0,316	
unc for gtv yield			3,458				7,567	**
			1,121				2,120	
adj R2	0,368		0,481		0,484		0,532	

Table 8.3

The tables above show the results from regressing the implied volatility of the AUD/USD, the JPY/USD and NZD/USD exchange rates on the uncertainty about fundamentals, proxied by disagreement. Model I includes uncertainty about a number of real fundamentals (budget balance, current account, GDP, investments, industrial production), whereas model II also includes monetary fundamentals (3 months interest rates, 10 year government yields). Significance of the coefficients is denoted by *, **, or *** for levels of 10%, 5%, or 1%. Shaded numbers are t-statistics.

Table 9.1-9.3 – Fundamentals: Expected return risk premium

	Australia							
Exp return RP	3m				12m			
	I		II		I		II	
constant	-0,023	***	-0,035	***	-0,058	***	-0,062	***
	-2,960		-3,620		-3,281		-2,622	
BB unc	0,001	***	0,002	***	0,005	***	0,006	***
	2,333		2,566		4,203		4,299	
CA unc	0,002	***	0,002	***	0,001		0,001	
	2,373		2,557		0,792		0,724	
GDP unc	-0,008		-0,010		0,031		0,021	
	-0,389		-0,449		0,770		0,526	
Inv unc	0,001		0,001		-0,004		-0,005	
	0,439		0,322		-0,697		-0,779	
IP unc	0,003		0,003		0,005		0,006	
	0,548		0,703		0,474		0,575	
unc for int rate			0,014				0,055	*
			0,570				1,809	
unc for gtv yield			0,036				-0,037	
			1,421				-0,818	
adj R2	0,132		0,137		0,141		0,158	

Table 9.1

	Japan							
Exp return RP	3m				12m			
	I		II		I		II	
constant	-0,001		-0,022	**	0,013		-0,017	
	-0,088		-2,168		0,955		-0,894	
BB unc	0,000		0,000		0,000		0,000	
	0,168		0,407		0,087		0,318	
CA unc	0,001	***	0,001	**	0,005	***	0,004	***
	2,465		2,231		3,057		2,497	
GDP unc	-0,020		-0,012		-0,005		-0,043	
	1,266		0,671		0,141		1,186	
Inv unc	-0,001		-0,001		-0,003		-0,001	
	-0,275		-0,219		-0,371		-0,143	
IP unc	-0,001		-0,004		-0,008		-0,015	**
	0,340		0,880		1,102		2,108	
unc for int rate			0,059				0,064	
			1,146				1,442	
unc for gtv yield			0,109	***			0,064	
			3,582				1,249	
adj R2	0,037		0,118		0,137		0,170	

Table 9.2

	New Zealand							
Exp return RP	3m				12m			
	I		II		I		II	
constant	-0,027	***	-0,036	***	-0,055	***	-0,075	***
	-3,015		-3,037		-2,704		-2,525	
BB unc	0,025	***	0,027	***	0,040	***	0,043	***
	4,295		4,730		3,685		3,921	
CA unc	0,001		0,001		0,014	**	0,016	**
	0,123		0,183		2,061		2,252	
GDP unc	0,006		-0,005		-0,026		-0,045	
	0,365		-0,243		-0,809		-1,349	
Inv unc	0,001		0,001		-0,004		-0,005	
	0,422		0,346		-0,584		-0,872	
IP unc	0,000		0,000		0,003		0,002	
	-0,076		-0,029		0,336		0,265	
unc for int rate			0,020				0,043	*
			0,823				1,683	
unc for gtv yield			0,019				0,017	
			0,864				0,409	
adj R2	0,194		0,205		0,214		0,229	

Table 9.3

The tables above show the results from regressing the expected return risk premium of the AUD/USD, the JPY/USD and NZD/USD exchange rates on the uncertainty about fundamentals, proxied by disagreement. Model I includes uncertainty about a number of real fundamentals, (budget balance, current account, GDP, investments, industrial production), whereas model II also includes monetary fundamentals (3 months interest rates, 10 year government yields). Significance of the coefficients is denoted by *, **, or *** for levels of 10%, 5%, or 1%. Shaded numbers are t-statistics.

Table 10.1-10.3 – Fundamentals: Volatility risk premium

Australia								
VRP	3m				12m			
	I		II		I		II	
constant	10,529	***	9,225	***	10,577	***	10,070	***
	9,843		8,083		11,636		10,970	
BB unc	-0,049		-0,025		0,028		0,038	
	-0,343		-0,187		0,187		0,255	
CA unc	0,777	***	0,711	***	0,723	***	0,741	***
	5,663		6,369		7,453		7,854	
GDP unc	-6,206	***	-6,253	***	-5,302	***	-4,925	***
	-2,362		-2,731		-2,984		-2,735	
Inv unc	0,048		-0,017		-0,178		-0,213	
	0,149		-0,056		-0,734		-0,954	
IP unc	-0,503		-0,224		-0,604		-0,683	
	-0,866		-0,474		-1,184		-1,366	
unc for int rate			11,469	*			-3,101	**
			1,739				-2,101	
unc for gtv yield			-3,105				4,214	*
			-0,902				1,694	
adj R2	0,473		0,506		0,549		0,560	

Table 10.1

Japan								
VRP	3m				12m			
	I		II		I		II	
constant	9,312	***	6,167	***	9,128	***	7,012	***
	7,693		4,226		9,630		5,285	
BB unc	0,073		0,118		0,135		0,156	
	0,480		0,877		1,201		1,444	
CA unc	0,122		0,085		0,143	*	0,049	
	1,308		1,062		1,848		0,699	
GDP unc	1,832		-2,533		2,520		-0,864	
	0,790		-1,079		1,221		-0,384	
Inv unc	-0,509		-0,014		-0,690		-0,243	
	-0,960		-0,031		-1,449		-0,484	
IP unc	1,006	***	1,326	***	0,828	**	1,332	***
	2,713		3,605		2,112		3,618	
unc for int rate			15,797	***			5,322	**
			2,735				2,123	
unc for gtv yield			11,581	***			4,431	
			2,676				1,406	
adj R2	0,102		0,263		0,129		0,193	

Table 10.2

	New Zealand							
VRP	3m				12m			
	I		II		I		II	
constant	8,779	***	6,363	***	8,473	***	6,737	***
	8,018		4,841		9,601		5,039	
BB unc	3,116	***	3,026	***	2,605	***	2,346	***
	4,317		4,635		4,989		5,009	
CA unc	0,573	**	0,506		0,958	***	0,988	***
	2,086		1,357		4,343		4,646	
GDP unc	2,228		0,586		0,606		-0,703	
	1,047		0,277		0,365		-0,396	
Inv unc	0,423		0,132		0,496		0,361	
	1,174		0,334		1,624		1,459	
IP unc	-0,739		-0,474		-0,292		-0,278	
	-1,349		-1,163		-0,605		-0,573	
unc for int rate			13,587	***			0,678	
			2,624				0,315	
unc for gtv yield			3,329				7,316	**
			1,096				2,115	
adj R2	0,372		0,483		0,489		0,535	

Table 10.3

The tables above show the results from regressing the volatility risk premium of the AUD/USD, the JPY/USD and NZD/USD exchange rates on the uncertainty about fundamentals, proxied by disagreement. Model I includes uncertainty about a number of real fundamentals (budget balance, current account, GDP, investments, industrial production), whereas model II also includes monetary fundamentals (3 months interest rates, 10 year government yields). Significance of the coefficients is denoted by *, **, or *** for levels of 10%, 5%, or 1%. Shaded numbers are t-statistics.