SCHOOL OF ECONOMICS AND MANAGEMENT
FACULTY OF SOCIAL SCIENCES
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CREATES Research Paper 2010-20

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Intertemporal Risk-Return Trade-Off in Foreign Exchange Rates*

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May 5, 2010

*The author acknowledges financial support from CREATES and the Danish Social Science Research Council. CREATES (Center for Research in Econometric Analysis of Time Series) is funded by the Danish National Research Foundation.

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Abstract: We investigate the intertemporal risk-return trade-off of foreign exchange (FX) rates for ten currencies quoted against the USD. For each currency, we use three risk measures simultaneously that pertain to that currency; its realized volatility, its realized skewness, and its value-at-risk. We apply monthly FX excess returns and monthly FX risk measures calculated from daily observations. We find that there is a positive and significant contemporaneous risk-return trade-off for most currencies. There is no evidence of noncontemporaneous risk-return trade-off. The risk-return trade-off changes during the recent financial crisis in that it becomes nonexistent for several currencies and negative for others.

Keywords: Foreign exchange rates; Risk-return trade-off; Realized volatility; Realized skewness; Value-at-risk; Financial crisis;

JEL Classifications: F31; G01; G15

1 Introduction

Since Merton (1973) there has been a focus on the risk-return trade-off at the stock market: a positive risk-return relationship implies that the higher the risk is, the higher is the expected return. Recently, the risk-return relationship on the stock market has seen a renewed investigation relying on cross sectional studies, cf. e.g. Ang, Hodrick, Xing and Zhang (2006) and Ang, Hodrick, Xing and Zhang (2009) as well as on intertemporal studies, cf. e.g. Bali (2008) and Bali, Dermirtas and Levy (2009). Inspired by the stock market analysis, we set out to investigate if there is a positive risk-return relationship in the FX market. In particular, we rely on time series analysis to study the intertemporal risk-return relationship on the FX market.

The current paper is related to Guo and Savickas (2008) who forecast FX returns using a linear model where the explanatory variables are various financial variables, including idiosyncratic stock market volatility. Guo and Savickas (2008) apply quarterly data for six foreign exchange rates against the USD. They find a strong relationship between the FX returns and stock market volatility. Lustig and Verdelhan (2007) consider the risk-return trade-off on currencies using portfolios sorted on interest rates. They find a cross sectional risk-return relationship where the risk is measured by consumption growth risk.

A recent strand of the international finance literature analyze FX carry trade strategies; that is self-financing portfolios consisting of long positions in currencies with high interest rates and short positions in currencies with low interest rates. According to the uncovered interest rate parity (UIP) carry trades are not profitable. Christiansen, Ranaldo and Söderlind (forthcoming) use a smooth transition model to show that typical FX carry trade strategies have much higher exposure to the stock market and are mean reverting when FX volatility is high. Their findings suggest that there is a risk-return relationship on the FX market. Brunnermeier, Nagel and Pedersen (2009) find evidence that sudden changes in exchange rates are related to unwinding of carry trade strategies due to funding constraints by the investors. They forecast future realized FX skewness (interpreted as crash risk) by interest rate differentials (foreign interest rate minus US interest rate) and FX excess returns. Burnside, Eichenbaum, Kleshchelski and Rebelo (2008) propose that carry trade strategies give high average payoffs due to peso problems, namely extreme and rare events.

We consider ten currencies of developed countries (all measured against the USD). The sample covers the period January 1987 to July 2009. We use daily exchange rates to calculate three monthly risk measures for each currency; the realized volatility, the realized skewness, and the value-at-risk. We investigate if the three risk measures are jointly able to explain the excess FX return using linear time series models. Moreover, we investigate if the intertemporal risk-return relationship is contemporaneous or occurs with a lead or lag. We find a strong contemporaneous risk-return relationship for most currencies under investigation. We find only limited evidence of noncontemporaneous risk-return relationships. It is important to consider all three risk measures simultaneously, because univariate models give rise to different conclusions than do multivariate models. Finally, we investigate if the current financial crisis has had an effect upon the FX risk-return relationship. We confirm this conjecture for most currencies.

The remaining part of the paper is structured as follows. In Section 2 we introduce the data. The econometric specification is laid out in Section 3 and the empirical results are discussed in Section 4. Finally, Section 5 concludes.

2 Data

2.1 Construction of Risk and Return Measures

The analysis is done on a monthly frequency, yet we use daily data to calculate monthly risk measures. The sample covers the period January 1987 to July 2009, thus we have 269 monthly observations. We consider the following currencies all measured as number of currency units per US dollar (USD): Australian dollar (AUD), Swiss franc (CHF), Canadian dollar (CAD), Danish krone (DKK), euro, UK pound (GBP), Japanese yen (JPY), Norwegian krone (NOK), New Zealand dollar (NZD), and Swedish krona (SEK). The exchange rates are available from DataStream. Before 1999 we use the German mark (DEM) in place of the euro.

We use the time subscript τ for the daily data and the subscript t for the monthly data. We denote by $P_{j\tau}$ the exchange rate for currency j at day τ against the USD ($P_{j\tau}$ of currency j per 1 USD), and $s_{j\tau} = \ln(P_{j\tau})$ is the corresponding log-exchange rate. We calculate the daily currency return for currency j as the log-differences,

$$r_{j\tau} = \Delta s_{j\tau} = \ln(P_{j\tau}) - \ln(P_{j\tau-1}) \tag{1}$$

We use these daily log-returns to calculate the following risk measures; realized volatility, realized skewness, and value-at-risk.

The realized variance is calculated by squaring and summing all the returns in a given month. We then use the square root of the realized variance, and it is denoted the realized volatility. The notation is RV_{jt} pertaining to currency j

in month t (where month t has n_t business days)

$$RV_{jt} = \sqrt{\sum_{\tau=1}^{n_t} r_{j\tau}^2} \tag{2}$$

The realized FX volatility is introduced by Andersen, Bollerslev, Diebold and Labys (2001) who use high frequency intradaily data to calculate the daily FX realized volatilities.

We use the absolute realized FX skewness as the second risk measure. Positive skewness for the foreign currency amounts to negative skewness for the USD and vice versa. Therefore we use the absolute realized skewness instead of the realized skewness itself. The skewness for currency j in month t is denoted $Skew_{jt}$ and is calculated as ($\overline{r_{jt}}$ and σ_{jt} are the average return and standard deviation in month t for currency j)

$$Skew_{jt} = \left| \frac{1}{n_t - 1} \sum_{\tau=1}^{n_t} \left(\frac{r_{j\tau} - \overline{r_{jt}}}{\sigma_{jt}} \right)^3 \right| \tag{3}$$

Brunnermeier et al. (2009) calculate quarterly realized FX skewness using daily data. They state that investment currencies (high interest currencies) are subject to crash risk, that is positive interest rate differentials are associated with negative FX skewness. Thus, according to Brunnermeier et al. (2009) FX skewness is an important and relevant risk measure.

The value-at-risk is calculated as the empirical 10% percentile of the daily returns for the particular month.[1] We denote it the VaR_{jt} and define it as a positive number as usual, so it is actually minus the 10% percentile.

$$\Pr\left(r_{j\tau} < -VaR_{jt}\right) = 0.10 \tag{4}$$

Using value-at-risk as a risk factor is related to the findings in Burnside et al. (2008). They show that FX carry trade returns are related to peso problems; that is rare extreme events. Although they do not use value-at-risk explicitly, it is an obvious risk measure following their analysis as peso problems are what the value-at-risk is trying to capture. Bali et al. (2009) investigate the intertemporal risk-return relationship on the stock market. They use alternative risk measures, namely the realized variance and the value-at-risk.

As the explained variable we use excess returns in addition to what is expected according to the Uncovered Interest Parity (UIP), which is similar to

[1] The quantiles are calculated using the quantile command in GAUSS.

Dueker and Neely (2007) and Brunnermeier et al. (2009). Let i_t be the log US 1-month interest rate and i_{jt} be the log foreign 1-month interest rate, then the excess return for currency j in month t is given as

$$z_{jt} = i_{jt-1} - i_{t-1} - r_{jt} \tag{5}$$

The interest rates are 1-month interbank interest rates downloaded from DataStream.[2]

2.2 Descriptive Statistics

Figures 1-4 shows time series plots for each currency of the excess return and the three risk measures. Figure 1 shows that the FX excess returns are highly erratic. There is no trend to be seen in the excess returns. At the end of the sample period, that is during the recent financial crisis, the excess returns are more variable. Figure 2 shows the realized volatilities. For most currencies the realized volatility has increased during the financial crisis. Figure 3 shows the realized skewness which is very erratic. The realized skewness is not notably different during the financial crisis. Figure 4 shows that in most cases the value-at-risk has increased lately. Again, the value-at-risk turns out to be very erratic.

Table 1 provides the means and standard deviations of the excess returns and the three risk measures for each currency. The average excess return is positive for all currencies under investigation except for CHF and JPY. The CHF and JPY are the so-called safe haven currencies, cf. Ranaldo and Söderlind (forthcoming). The variability of the excess returns is quite different across the currencies; the standard deviation is lowest for CAD (2.1) and highest for JPY (3.7). The average realized volatility is about the same size for all currencies (about 3) except that it is much smaller for CAD. The standard deviation of the realized volatility is spread out between 1.0 (DKK) and 1.7 (AUD). The average realized skewness lies within a narrow rage $(0.4 - 0.5)$, so the return series are only slightly skewed on average. The variability of the skewness is also about the same for all currencies $(0.4 - 0.5)$. The value-at-risk is on average about the same size $(0.8 - 0.9)$ except it is on average much lower for CAD (0.5) and somewhat higher for CHF (1.0). The standard deviation of the value-at-risk does not vary much across currencies.

[2] For CAD the interbank rate is not available until May 1990, before that the Bankers Acceptance rate is used.

3 Econometric Specification

To investigate the risk-return relationship on the FX market, we estimate the following univariate models for each currency j

$$z_{jt} = \alpha_j + \beta_j Risk_{jt} + \varepsilon_{jt} \tag{6}$$

where we consider a given risk measure $Risk_{jt}$ at a time for currency j at time t. $\varepsilon_{jt} \sim N(0,1)$ is the error term. If the coefficient β_j is significant and positive, then there is a positive risk-return relationship for that currency pertaining to that particular risk measure. The risk measures we consider are $Risk_{jt} = \{RV_{jt}, Skew_{jt}, VaR_{jt}\}$.

Yet, here we want to allow for risk impacts upon the FX returns stemming from different risk measures at the same time. Thus, to investigate the risk-return relationship on the FX market more thoroughly, we therefore use the following multivariate linear model for each currency j:

$$z_{jt} = \alpha_j + \beta_{jRV} RV_{jt} + \beta_{jSkew} Skew_{jt} + \beta_{jVaR} VaR_{jt} + \varepsilon_{jt} \tag{7}$$

where $\varepsilon_{jt} \sim N(0,1)$ is the error term. In equation (7) we investigate whether current risk variables have joint explanatory power for the current FX excess returns, namely if the coefficients $\{\beta_{jRV}, \beta_{jSkew}, \beta_{jVaR}\}$ are jointly significant. This is tested by a joint Wald test ($\chi^2(3)$ distributed) of the null hypothesis: $\beta_{jRV} = \beta_{jSkew} = \beta_{jVaR} = 0$. Moreover, by including three risk measures in the same regression we obtain some information as to which risk measure is best at capturing the risk-return relationship.

The methodology is related to Guo and Savickas (2008) who use a multivariate linear model to investigate which financial variables explain FX returns. However, instead of forecasting future FX returns, we investigate how the excess FX returns are related to various FX risk measures.

Furthermore, we investigate whether the risk-return relationship is noncontemporaneous. First, we do this by considering 1-period lagged explanatory variables (for simplicity we use unchanged notation from equation (7)):

$$z_{jt} = \alpha_j + \beta_{jRV} RV_{jt-1} + \beta_{jSkew} Skew_{jt-1} + \beta_{jVaR} VaR_{jt-1} + \varepsilon_{jt} \tag{8}$$

If the coefficients $\{\beta_{jRV}, \beta_{jSkew}, \beta_{jVaR}\}$ are jointly significant it implies that there is a delayed risk-return trade-off between lagged risk and current returns.

Second, we investigate if there is a relation between the current risk measures and the previous month's excess return. In practice, it is done by running regressions where the explanatory variables are leaded

$$z_{jt} = \alpha_j + \beta_{jRV} RV_{jt+1} + \beta_{jSkew} Skew_{jt+1} + \beta_{jVaR} VaR_{jt+1} + \varepsilon_{jt} \quad (9)$$

Again, if the coefficients $\{\beta_{jRV}, \beta_{jSkew}, \beta_{jVaR}\}$ are jointly significant, then there is a trade-off between risk and return that is not contemporaneous, namely between current return and future risk.

We investigate if the recent financial crisis has an effect upon the FX risk-return relationship. The NBER dates the beginning of the most recent recession to December 2007 and it is still ongoing when the sample ends in July 2009. According to Melvin and Taylor (2009) the crisis on the FX market started a little earlier, namely in August 2007. Thus, we define a crisis variable which is equal to one after August 2007 and zero before;

$$Crisis_t = \begin{cases} 0 & t < 2007M07 \\ 1 & t \geq 2007M08 \end{cases} \quad (10)$$

Then we estimate the contemporaneous model again, but now allowing the intercept and slope coefficients to change during the crisis period:

$$\begin{aligned} z_{jt} &= \alpha_j + \beta_{jRV} RV_{jt} + \beta_{jSkew} Skew_{jt} + \beta_{jVaR} VaR_{jt} + \gamma_j Crisis_t \\ &+ \delta_{jRV} Crisis_t RV_{jt} + \delta_{jSkew} Crisis_t Skew_{jt} + \delta_{jVaR} Crisis_t VaR_{jt} + \varepsilon_{jt} \end{aligned} \quad (11)$$

During the crisis, the intercept equals $(\alpha_j + \gamma_j)$ and the slope coefficients are $\{\beta_{jRV} + \delta_{jRV}, \beta_{jSkew} + \delta_{jSkew}, \beta_{jVaR} + \delta_{jVaR}\}$. The null hypothesis of no changes in the risk-return relationship during the financial crisis is as follows: $\gamma_j = \delta_{jRV} = \delta_{jSkew} = \delta_{jVaR} = 0$.

4 Empirical Risk-Return Relationship

The linear models are estimated using the ordinary least squares (OLS) estimation technique. The estimation is conducted in EViews and inference is based upon Newey and West (1987) standard errors. To make the coefficients comparable, we use standardized explanatory variables (unchanged notation), that is they have mean zero and unit variance.

4.1 Univariate Risk-Return Models

Table 2 reports the results from the univariate risk-return equation (6) where the explanatory variable is first the realized volatility, second the realized skewness, and third the value-at-risk. The explanatory power of the realized volatility is fairly low throughout; the adjusted R^2 reaches its highest level for CHF at 9%. For some currencies the effect from the realized volatility is positive (CHF and JPY) and for some it is negative (AUD, GBP, and NZD).

The explanatory power of the skewness is very low; in most cases the adjusted R^2 is around zero.

The value-at-risk has explanatory power for some currencies and its estimated effect is positive. For CHF, DKK, EURO, and JPY the adjusted R^2 lies between 19% and 34%, for the other currencies the explanatory power is below 5%. Thus, for at least four some currencies, there is a positive risk-return trade-off present when the risk is measured by the currency's own value-at-risk.

Overall, the results from the univariate models shows that the value-at-risk is the most promising risk measure when considering FX risk-return trade-off. Moreover, the risk-return trade-off exists only for four out of ten currencies.

4.2 Contemporaneous Risk-Return Trade-Off

Table 3 reports the results from estimating equation (7). For all currencies the explanatory power of the three risk measures is strong. The adjusted R^2 exceeds 43% for all currencies (except for NOK for which it is only 22%). In the univariate models, the explanatory power is much lower. This shows us that the multivariate model provides a much better description of the relation between FX excess returns and FX risk. Thus, it is important to include all three risk measures simultaneously when considering the FX risk-return trade-off. Also, the joint Wald test of $\beta_{jRV} = \beta_{jSkew} = \beta_{jVaR} = 0$ shows that the explanatory variables are jointly significant for all currencies under investigation.

The intercept terms α_j are only significantly negative for CHF and JPY. These are the safe haven currencies analyzed in Ranaldo and Söderlind (forthcoming). Thus, for the safe haven currencies, the risk adjusted excess returns are negative. This compares with the average excess returns which are also only negative for the JPY and CHF, cf. Table 1. For the remaining currencies, the intercept terms α_j are positive, and generally significantly so (exceptions are EURO and SEK). These currencies have the opposite characteristics, namely that the risk adjusted excess returns are positive as are their average excess returns. So, we find strong differences between the risk adjusted excess returns of safe haven currencies and the other "unsafe" currencies.

The realized volatility has a negative and significant effect upon the excess returns ($\widehat{\beta}_{jRV} < 0$). This applies for all currencies. In contrast, the effect of the value-at-risk is positive ($\widehat{\beta}_{jVaR} > 0$). This effect is also significant for all currencies. It appears that the realized volatility and value-at-risk coefficients are of about the same absolute size in many cases, thus we calculate the Wald $\chi^2(1)$ test statistic for the null hypothesis: $\beta_{jRV} + \beta_{jVaR} = 0$. This hypothesis is only rejected for four currencies, namely CHF, DKK, EURO, and JPY. Thus, only for these currencies do the effects from the realized volatility and value-at-risk not cancel out. For all other currencies under investigation, we cannot reject that the effects from the two risk measures cancel out.

The effect of the realized skewness on the excess returns is positive ($\widehat{\beta}_{jSkew}$) as expected given the findings in Brunnermeier et al. (2009). The relationship is generally significant; only for CHF and NOK is the skewness insignificant in explaining the excess returns.

To test if the risk variables are jointly significant, we test jointly if the skewness is insignificant and at the same time if the realized volatility and the value-at-risk cancel out. We use the $\chi^2(2)$ distributed Wald test statistic of the hypothesis $\beta_{jRV} + \beta_{jVaR} = \beta_{jSkew} = 0$. This hypothesis is rejected for all currencies except NOK and SEK. So, for most currencies the risk measures are jointly significant in explaining the FX excess returns. The effects from the risk measures upon the excess return are positive.

Overall, there is significant contemporaneous risk-return trade-off for the currencies under investigation. Moreover, the risk-return relationship has the expected sign, namely the larger the risks are, the greater is the excess return on that currency. So, investors are compensated for bearing FX risk. This finding compares well with Guo and Savickas (2008) who find that the FX returns are greater the greater the stock market volatility is. The stock market volatility is also some kind of risk measure. Moreover, the findings are in accordance with the carry trade literature that documents a relation between carry trade performance and FX volatility.

4.3 Delayed Risk-Return Trade-Off

In Table 4 we show the results from estimating the lagged risk-current return relationship, cf. equation (8). The lagged risk measures are not jointly significant in explaining the current excess returns (the only exception is DKK).

Table 5 shows the results from estimating the linear model for the current risk and lagged excess returns, cf. equation (9). We find only little evidence of future risk having a bearing on the current excess returns. Only for CHF and JPY are the future risk measures jointly significant in explaining the excess returns. Still, even for these currencies, the explanatory power is very low; the adjusted R^2 only amounts to $2\% - 3\%$.

So, overall, we conclude that the risk-return trade-off only occurs between contemporaneous risk and return measures. There is no evidence of non-timely patterns.

4.4 Risk-Return Trade-Off during the Financial Crisis

In Table 6 we estimate the contemporaneous risk-return relationship where we allow the intercept and slope coefficients to change during the current financial crisis according to equation (11). The joint Wald test shows that the parameters have changed significantly for all currencies (expect GBP). The observed change in the risk-return trade-off is not surprising, provided that Melvin and Taylor (2009) find that the recent financial crisis also affects the FX markets.

To get a better overview of the risk-return relationship during the financial crisis, we estimate the contemporaneous risk-return equation (7) where we restrict the sample to cover the financial crisis, namely $2007M08 - 2009M06$. The results are provided in Table 7.

Overall, the explanatory power of the regressions are strong. Again, the risk adjusted excess returns are positive except for CHF and JPY (as seen from the sign of the estimated intercept $\widehat{\alpha}_j$). For all currencies, the effect of the realized volatility is negative ($\widehat{\beta}_{jRV} < 0$) and the effect from the value-at-risk is positive ($\widehat{\beta}_{jRaR}$). For about half the currencies, the two effects cancel out, in that we cannot reject that $\beta_{jRV} + \beta_{jVaR} = 0$. Interestingly, it is not for the same currencies as for the entire period.

The skewness effect is not significant in itself for any of the currencies ($\widehat{\beta}_{jSkew}$ is insignificant). In many cases the effect from the skewness is negative ($\widehat{\beta}_{jSkew} < 0$). In contrast, for the entire period the skewness effect is positive and generally significant.

The joint hypothesis that the realized volatility and the value-at-risk cancel out as well as the skewness being insignificant ($\beta_{jRV} + \beta_{jVaR} = \beta_{jSkew} = 0$) is not rejected for half the currencies, namely for DKK, EURO, GBP, NZD, and SEK. For the entire period, this applies only for NOK and SEK. So, the risk-return relationship has become weaker during the financial crisis, in that it is insignificant for five instead of two currencies.

For the full sample period the risk-return relationship is positive and significant ($\widehat{\beta}_{jRV} + \widehat{\beta}_{jVaR} = \widehat{\beta}_{jSkew} > 0$) for all currencies except NOK and SEK for which there is no risk-return trade-off. During the financial crisis, there is only a positive and significant risk-return trade-off for CHF and JPY. So, again the two safe haven currencies stand out. The risk-return trade-off is significant but negative for AUD, CAD, and NOK ($\widehat{\beta}_{jRV} + \widehat{\beta}_{jVaR} = \widehat{\beta}_{jSkew} < 0$). So, NOK changes from having no risk-return trade-off during the entire sample period to having negative risk-return trade-off during the financial crisis. For DKK, EURO, GNP, NZD, and SEK we find no evidence of a risk-return trade-off during the financial crisis. Out of these five currencies, this only applies to SEK for the entire sample period.

Overall, during the recent financial crisis, the risk-return trade-off is very different than during the entire sample period. In particular, it is only significant and positive for the safe haven currencies. For the other currencies it is either negative or nonexisting. So, the risk-return trade-off is weaker during the financial crisis.

5 Conclusion

We have used three risk measures to explain the FX excess returns for ten currencies, namely realized volatility, realized skewness, and value-at-risk. During the sample period $1987M01$ to $2009M07$, the risk-return trade-off is strong. The risk-return trade-off is contemporaneous, not leaded or lagged. It is important to include all three risk measures simultaneously when analyzing the risk-return trade-off. During the recent financial crisis, the risk-return trade-off is weaker and it is even been reversed to negative in some cases. The safe haven currencies CHF and JPY differ from other currencies in several ways.

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Table 1: Descriptive Statistics

	AUD	CAD	CHF	DKK	EURO	GBP	JPY	NOK	NZD	SEK
	Means									
z	0.57	0.20	-0.53	0.35	0.10	0.46	-1.73	0.41	0.70	0.19
RV	3.04	1.77	3.27	2.94	2.97	2.72	3.09	3.10	3.04	3.09
Skew	0.47	0.46	0.44	0.45	0.43	0.50	0.56	0.47	0.51	0.44
VaR	0.89	0.53	1.03	0.91	0.92	0.81	0.94	0.93	0.90	0.94
	Standard Deviations									
z	3.34	2.10	3.41	3.14	3.18	2.98	3.72	3.09	3.37	3.36
RV	1.72	1.06	0.97	0.96	0.97	1.10	1.21	1.41	1.57	1.35
Skew	0.44	0.41	0.38	0.39	0.40	0.44	0.49	0.40	0.44	0.38
VaR	0.57	0.35	0.42	0.38	0.37	0.34	0.48	0.46	0.48	0.50

Notes: The table shows the means and standard deviations of the excess returns (z), realized volatility (RV), realized skewness (Skew), and Value-at-Risk (VaR) for 10 currencies all measued against the USD. The monthly sample covers the period 1987 to 2009.

Table 2: Univariate Risk-Return Relationship

	AUD	CAD	CHF	DKK	EURO	GBP	JPY	NOK	NZD	SEK
Cons	0.57 **	0.20	-0.53 **	0.35	0.10	0.46 **	-1.73 ***	0.41 *	0.70 ***	0.19
RV	-0.97 **	-0.34	0.43 *	-0.04	-0.08	-0.78 ***	1.14 ***	-0.45	-0.78 **	-0.59
Adj R^2	0.08	0.02	0.01	0.00	0.00	0.07	0.09	0.02	0.05	0.03
Cons	0.57 **	0.20	-0.53 **	0.35	0.10	0.46 **	-1.73 ***	0.41 *	0.70 ***	0.19
Skew	-0.17	-0.12	-0.24	-0.02	-0.06	0.08	0.70 ***	0.02	-0.13	-0.09
Adj R^2	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00
Cons	0.57 **	0.20	-0.53 **	0.35	0.10	0.46 **	-1.73 ***	0.41 *	0.70 ***	0.19
VaR	0.05	0.27	1.91 ***	1.39 ***	1.38 ***	0.67 *	2.17 ***	0.54	0.49	0.80 *
Adj R^2	0.00	0.01	0.31	0.19	0.19	0.05	0.34	0.03	0.02	0.05

Notes: The table shows the parameter estimates from linear models where the excess return on a given currency is explained by a constant (Cons) and one explanatory variable; first the contemporaneous realized volatility (RV), second the contemporaneous realized skewness (Skew), and third the contemporaneous value-at-risk (VaR). The explanatory variables are standardized. Newey and West (1987) standard errors are applied. ***/**/* indicates significance at 1%/5%/10% level of significance.

Table 3: Contemporaneous Risk-Return Relationship

	AUD	CAD	CHF	DKK	EURO	GBP	JPY	NOK	NZD	SEK
Cons	0.57 ***	0.20 *	-0.53 ***	0.35 *	0.10	0.46 ***	-1.73 ***	0.41 **	0.70 ***	0.19
RV	-4.94 ***	-3.42 ***	-2.19 ***	-2.64 ***	-2.79 ***	-2.95 ***	-2.52 ***	-2.14 **	-4.52 ***	-4.02 ***
Skew	0.61 ***	0.13 **	0.13	0.28 **	0.37 **	0.38 ***	0.76 ***	0.14	0.38 **	0.35 **
VaR	4.46 ***	3.39 ***	3.55 ***	3.41 ***	3.54 ***	2.89 ***	4.16 ***	2.19 ***	4.39 ***	4.14 ***
Adj R^2	0.43	0.46	0.49	0.49	0.50	0.48	0.48	0.22	0.49	0.50
H_0: $\beta_{jRV}+\beta_{jVaR}=0$	1.0	0.0	53.5 ***	11.1 ***	13.5 ***	0.1	80.5 ***	0.0	0.1	0.1
H_0: $\beta_{jRV}+\beta_{jVaR}=\beta_{jSkew}=0$	10.0 ***	5.5 *	53.6 ***	12.5 ***	17.7 ***	8.3 **	110.0 ***	0.5	5.2 *	4.6
H_0: $\beta_{jRV}=\beta_{jSkew}=\beta_{jVaR}=0$	72.0 ***	106.9 ***	237.2 ***	258.3 ***	318.2 ***	226.4 ***	276.5 ***	9.0 **	198.1 ***	347.5 ***

Notes: The table shows the parameter estimates from linear models where the excess return on a given currency is explained by a constant (Cons), the contemporaneous realized volatility (RV), the contemporaneous realized skewness (Skew), and the contemporaneous value-at-risk (VaR). The explanatory variables are standardized. Wald test statistics are provided. Newey and West (1987) standard errors are applied. ***/**/* indicates significance at 1%/5%/10% level of significance.

Table 4: Lagged Risk-Return Relationship

	AUD	CAD	CHF	DKK	EURO	GBP	JPY	NOK	NZD	SEK
Cons	0.56 **	0.20	-0.53 **	0.34	0.11	0.45 **	-1.73 ***	0.41 *	0.68 ***	0.18
RV(-1)	-0.99	0.25	-0.45 *	-0.43	-0.22	-0.49	0.13	-0.14	-0.18	-0.68
Skew(-1)	0.02	0.11	0.03	0.35 *	0.21	-0.22	0.21	0.04	-0.15	0.15
VaR(-1)	1.18 *	-0.21	0.21	0.50 **	0.19	0.11	0.20	0.16	0.25	0.52
Adj R^2	0.02	-0.01	0.00	0.01	-0.01	0.02	0.00	-0.01	-0.01	0.00
H_0: $\beta_{jRV}=\beta_{jSkew}=\beta_{jVaR}=0$	5.3	2.2	3.0	7.0 *	1.5	5.4	3.6	0.5	0.6	2.1

Notes: The table shows the parameter estimates from linear models where the excess return on a given currency is explained by a constant (Cons), the 1-month lagged realized volatility (RV(-1)), the 1-month lagged realized skewness (Skew(-1)), and the 1-month lagged value-at-risk (VaR(-1)). The explanatory variables are standardized. Wald test statistics are provided. Newey and West (1987) standard errors are applied. ***/**/* indicates significance at 1%/5%/10% level of significance.

Table 5: Leaded Risk-Return Relationship

	AUD	CAD	CHF	DKK	EURO	GBP	JPY	NOK	NZD	SEK
Cons	0.56 **	0.23	-0.52 **	0.35	0.10	0.45 **	-1.73 ***	0.41 *	0.69 ***	0.19
RV(+1)	0.22	0.42	0.69 **	0.14	0.25	-0.23	0.77	0.12	0.14	-0.43
Skew(+1)	0.11	-0.12	-0.38 *	-0.23	-0.37 **	0.09	-0.11	-0.16	0.02	0.17
VaR(+1)	-0.86	-0.43	-0.25	-0.04	-0.13	-0.19	-0.03	-0.49	-0.57	-0.02
Adj R^2	0.03	0.00	0.02	-0.01	0.00	0.01	0.03	0.01	0.01	0.01
H_0: $\beta_{jRV}=\beta_{jSkew}=\beta_{jVaR}=0$	4.6	2.6	8.2 **	2.2	5.3	1.8	8.6 **	2.0	1.7	2.8

Notes: The table shows the parameter estimates from linear models where the excess return on a given currency is explained by a constant (Cons), the 1-month leaded realized volatility (RV(+1)), the 1-month leaded realized skewness (Skew(+1)), and the 1-month leaded value-at-risk (VaR(+1)). The explanatory variables are standardized. Wald test statistics are provided. Newey and West (1987) standard errors are applied. ***/**/* indicates significance at 1%/5%/10% level of significance.

Table 6: Risk-Return Relationship with Crisis Indicator

	AUD	CAD	CHF	DKK	EURO	GBP	JPY	NOK	NZD	SEK
Cons	0.52 **	0.26 **	-0.58 ***	0.35 *	0.08	0.50 ***	-1.85 ***	0.60 ***	0.56 ***	0.30
RV	-4.32 ***	-2.65 ***	-2.20 ***	-2.54 ***	-2.67 ***	-2.82 ***	-2.66 ***	-1.87 **	-4.45 ***	-3.80 ***
Skew	0.48 **	0.12 **	0.18	0.33 **	0.40 **	0.35 ***	0.89 ***	0.27	0.28 *	0.42 ***
VaR	4.56 ***	3.04 ***	3.44 ***	3.53 ***	3.58 ***	2.92 ***	4.14 ***	2.89 ***	4.13 ***	4.52 ***
Crisis	3.63 ***	2.36 ***	0.32	0.40 **	0.88 **	0.52	0.35	0.70	2.15 **	0.18
Crisis*RV	-2.67 **	-2.21 ***	-1.00	-0.43	-0.86	-0.97	-0.56	-1.99	-1.42 *	-1.20 **
Crisis*Skew	0.03	-0.27	-1.41 **	-0.86	-0.26	1.09	-1.67 ***	-2.84 **	2.68	-0.80
Crisis*VaR	0.91	0.90	1.64 **	-0.53	-0.01	0.29	0.97	-0.17	1.86 *	0.00
Adj R^2	0.51	0.53	0.50	0.50	0.50	0.48	0.48	0.31	0.53	0.52
H_0: $\gamma_j=\delta_{jRV}=\delta_{jSkew}=\delta_{jVaR}=0$	24.0 ***	27.5 ***	18.6 ***	15.6 ***	19.5 ***	7.4	13.4 ***	23.1 ***	7.9 *	15.1 ***

Notes: The table shows the parameter estimates from linear models where the excess return on a given currency is explained by a constant (Cons), the contemporaneous realized volatility (RV), the contemporaneous realized skewness (Skew), the contemporaneous value-at-risk (VaR), the contemporaneous crisis indicator variable (Crisis), Crisis*RV, Crisis*Skew, and Crisis*VaR. RV, Skew, and VaR are standardized. The crisis indicator is equal to 1 during the FX crisis beginning in August 2007, cf. Melvin and Taylor (2009). Wald test statistics are provided. Newey and West (1987) standard errors are applied. ***/**/* indicates significance at 1%/5%/10% level of significance.

Table 7: Contemporaneous Risk-Return Relationship during Financial Crisis

	AUD	CAD	CHF	DKK	EURO	GBP	JPY	NOK	NZD	SEK
Cons	4.15 ***	2.62 ***	-0.26	0.75	0.95	1.03	-1.50 ***	1.30 *	2.71 **	0.48
RV	-7.00 ***	-4.86 ***	-3.20 ***	-2.97 ***	-3.52 ***	-3.79 ***	-3.23 **	-3.86 ***	-5.87 ***	-5.00 ***
Skew	0.51	-0.16	-1.23	-0.53	0.14	1.44	-0.79	-2.57 **	2.96	-0.38
VaR	5.47 ***	3.94 ***	5.09 ***	3.00 ***	3.57 ***	3.21 ***	5.11 ***	2.72 ***	5.99 ***	4.52 ***
Adj R^2	0.64	0.65	0.58	0.33	0.36	0.39	0.68	0.42	0.47	0.45
H_0: $\beta_{jRV}+\beta_{jVaR}=0$	23.1 ***	6.6 **	15.7 ***	0.0	0.0	0.6	71.9 ***	4.4 **	0.0	0.7
H_0: $\beta_{jRV}+\beta_{jVaR}=\beta_{jSkew}=0$	56.4 ***	7.5 **	26.9 ***	0.1	0.0	1.6	71.9 ***	7.0 **	3.2	0.9
H_0: $\beta_{jRV}=\beta_{jSkew}=\beta_{jVaR}=0$	82.4 ***	52.2 ***	34.2 ***	25.9 ***	37.3 ***	41.9 ***	73.6 ***	16.8 ***	30.1 ***	108.3 ***

Notes: The table shows the parameter estimates from linear models where the excess return on a given currency is explained by a constant (Cons), the contemporaneous realized volatility (RV), the contemporaneous realized skewness (Skew), and the contemporaneous value-at-risk (VaR). The explanatory variables are standardized. Wald test statistics are provided. The sample covers the period August 2007 to July 2009. Newey and West (1987) standard errors are applied. ***/**/* indicates significance at 1%/5%/10% level of significance.

Figure 1: Excess Returns

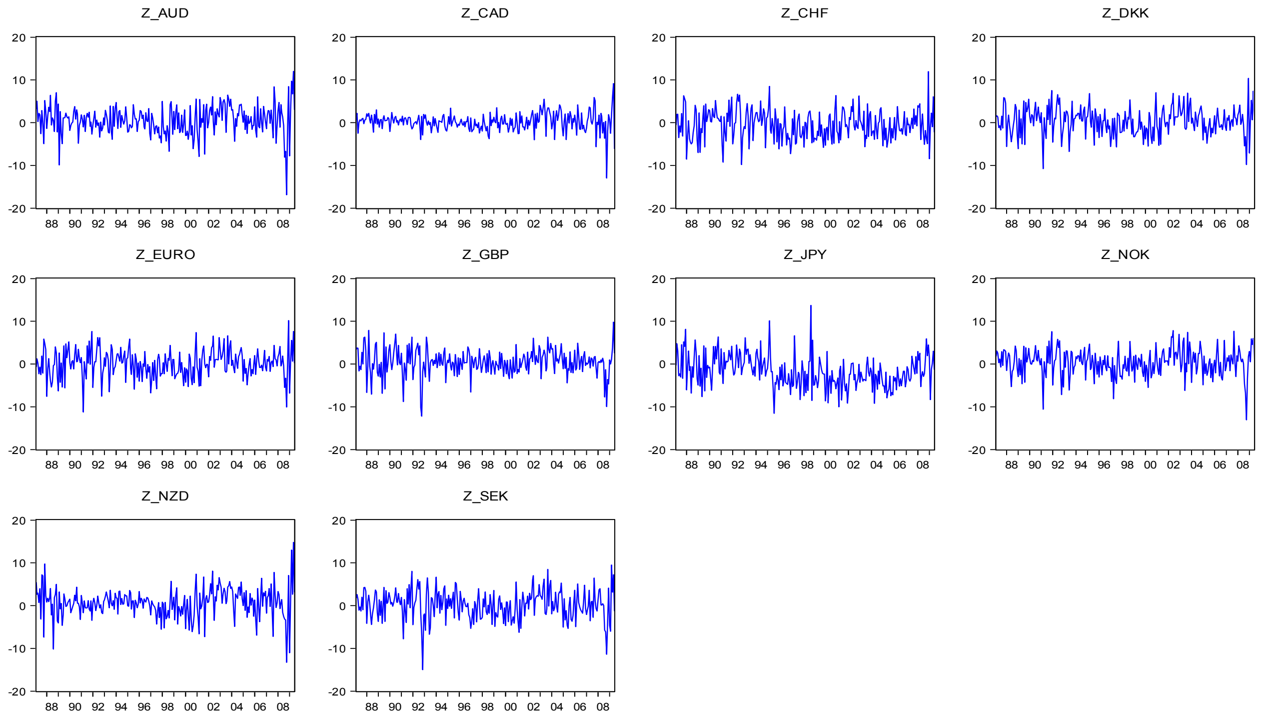


Figure 2: Realized Volatility

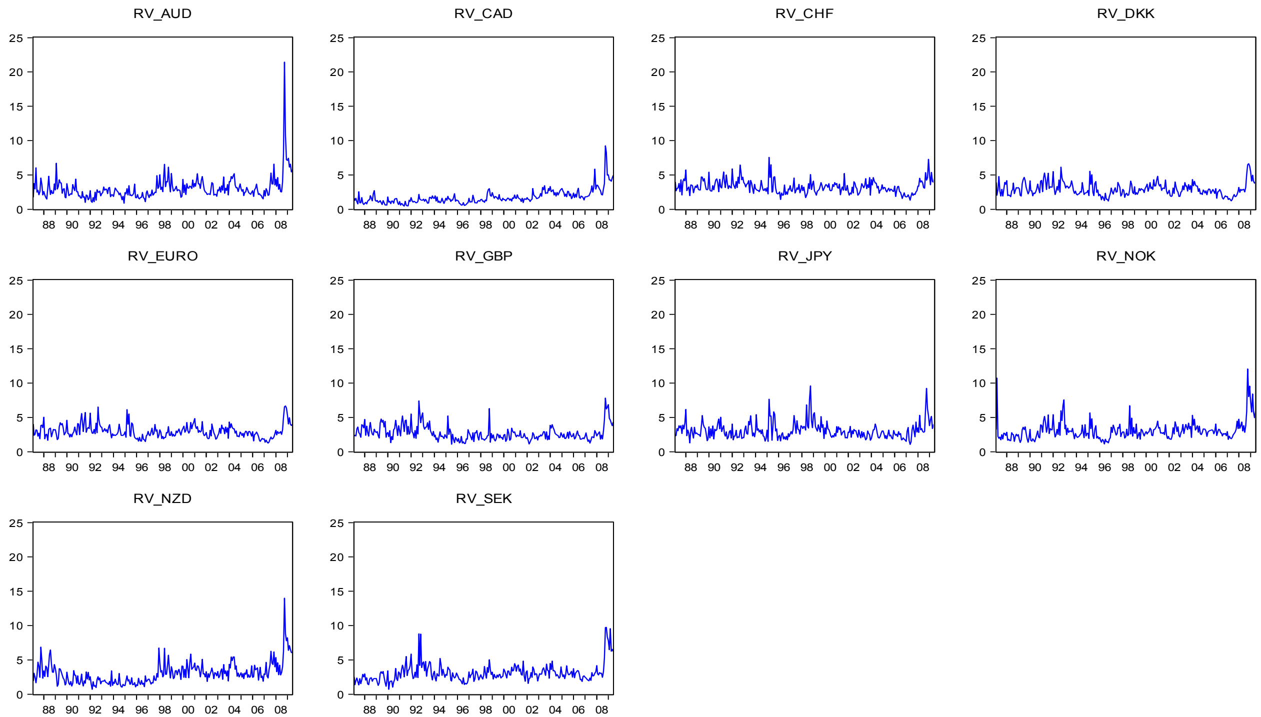


Figure 3: Skewness

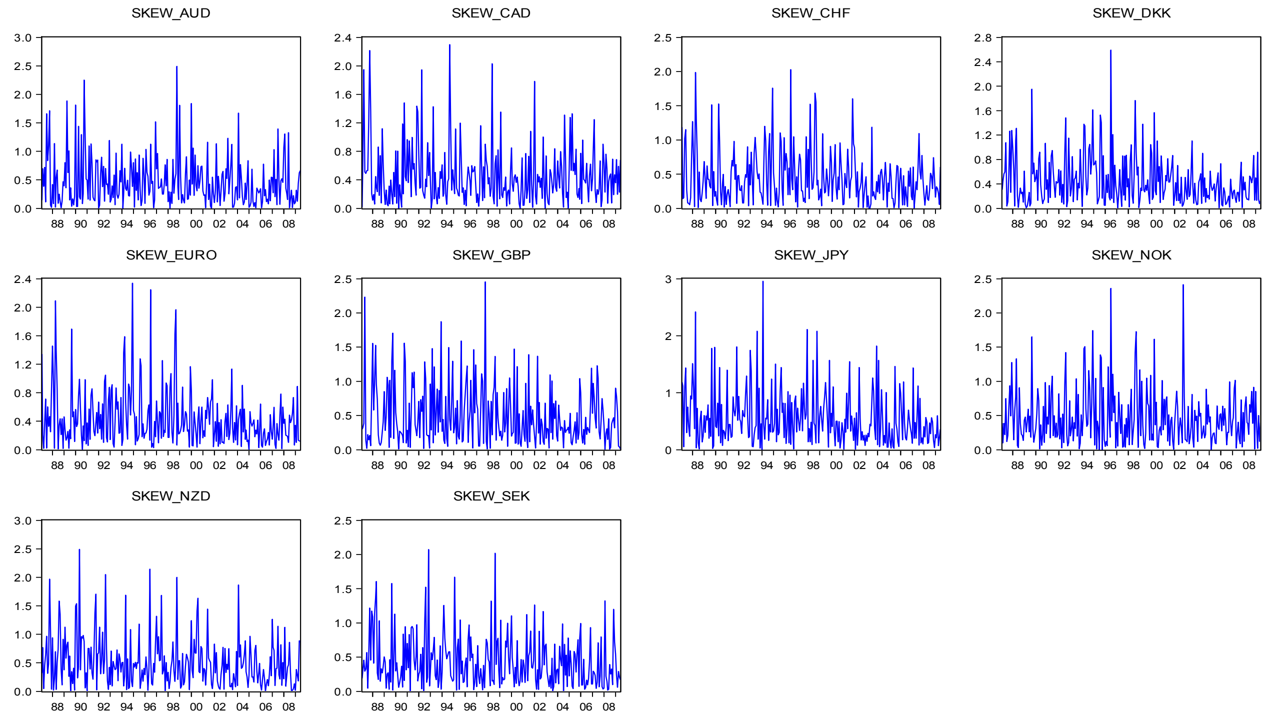
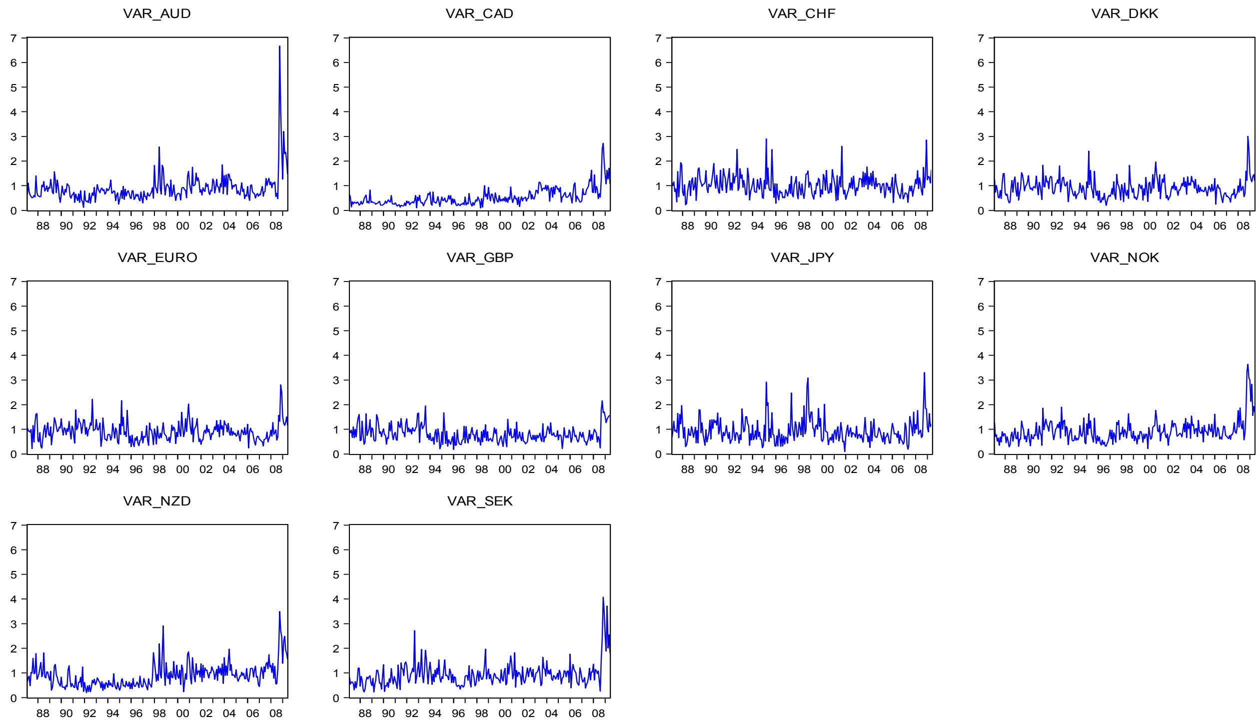


Figure 4: Value-at-Risk



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