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Defining the Currency Hedging Ratio

A Robust Measure

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Preface & Acknowledgements

This thesis has been written as a final assignment of the Master in Economics & Business, with a specialisation in Financial Economics. The subject of my thesis came to my attention by following the seminar International Investments during this Masters course.

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Abstract

In this thesis research has been done to find the optimal hedge ratio to hedge currency risk. Two international diversified portfolios are formed; one with developed countries and one with emerging countries, and five different hedging strategies are tested. The Sharpe ratios of the portfolios are calculated for several time periods between 1998 and 2010 from the perspective of an American investor. The results show that for both portfolios the hedge ratios calculated with DCC-Garch give the best Sharpe-ratio for the whole period; for specific time intervals there are other strategies that perform better. Since in practice it seems almost impossible to predict the exchange rate DCC-Garch could be an useful method because this thesis shows that it performs best based on historic data.

Keywords: Hedge ratios, International Diversification, DCC-Garch, Currency risk

JEL class.: C32, G10, G15

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1. Introduction

This thesis will research the effect of different hedging strategies on internationally diversified portfolios consisting of stocks and bond. The last couple of decades investing abroad gained more and more popularity and as a consequence of that investors have more exposure to currency risk. By investing internationally a lot of risk is diversified away, but on the other hand currency risk comes into play. Currency risk has a big share in the total risk of a portfolio and therefore it is important to manage this risk properly. It can have a big impact on your portfolio returns when the currency aspect is ignored. In the literature there is no consensus what the optimal strategy is when it comes to hedging. For instance Perold and Schulman (1988) conclude that currency risk should always be fully hedged; on the other hand some argue (e.g. Froot, 1993) that no hedging at all is the best strategy.

The goal of this thesis is to test which hedging strategy gives the best result in terms of returns and risk for internationally diversified portfolios. To test the hedging effectiveness of different hedging strategies two internationally diversified portfolios are formed, one with developed countries and one with emerging countries. To determine the weights of the portfolios the Sharpe ratio of the portfolios is maximized. It is assumed that the investor lives in the United States so he wants to hedge the risk of an appreciating dollar. Five strategies are used to hedge the portfolio: full hedging, no hedging, regret theory, OLS hedging and DCC-Garch hedging. The first four strategies are static strategies, with DCC-Garch a dynamic hedge ratio will be calculated (i.e. a different hedge ratio every day). Different periods are investigated to see which strategy performs best. The whole sample includes appreciating and depreciating periods of the dollar and therefore it can be hard to draw conclusions which strategy performs best when the dollar is appreciating or depreciating. The in-sample period for the whole sample runs from January 1998 till December 2004 and the out-of-sample runs from January 2005 till March 2010. The in-sample period is used to form the portfolios and to calculate the parameters or hedge ratios. Three different sub periods are tested for; one period in which the dollar is clearly depreciating, one in which it is appreciating and one in which it is slightly depreciating.

In comparison with other studies this is the first time that the hedging effectiveness of DCC-Garch is tested for a portfolio of emerging countries. Two studies (Hautsch & Inkmann, 2003; Zhang, 2003) have examined the performance of DCC-Garch but they only did this for developed countries. Also these studies used fewer countries in their portfolios and/or they used a shorter sample period to calculate the hedge ratios with DCC-Garch. Therefore this study is more robust because of the choice of the time period and the countries. More conclusions can be drawn because different out-of-sample periods are used in which the course of the dollar is different.

The rest of the paper is organized in the following way. Chapter 2 provides a literature review of previous studies. Chapter 3 describes the methodology used to form the portfolios and to calculate the hedging ratios. Chapter 4 describes the data used and in Chapter 5 the results will be discussed. Finally Chapter 6 will conclude.

2. Literature Review

Solnik (1974) was one of the first economists that realized that international diversification offered benefits over investing only in the domestic country. Diversification eliminates idiosyncratic risk from a portfolio leading to a lower variance. By diversifying internationally more idiosyncratic risk can be eliminated because country-specific risk is mitigated through diversification. On the other hand another risk comes into play namely currency risk, as an investor you run the risk that the domestic currency appreciates while his investments are in foreign currency. This will lead to lower returns in the domestic currency after converting the foreign currency back into domestic currency. To overcome this problem an investor can hedge his currency exposure with derivatives. Well-known examples of derivatives are forwards, futures and options. After selecting the derivative another question can be raised: how much of your currency exposure should be hedged? A simple answer to this question would be a strategy to hedge all currency risk, i.e. a hedge ratio of 100%, but a lot of alternative methods to calculate the hedge ratio are developed.

Basically two types of hedging can be distinguished: static hedging and dynamic hedging. With static hedging the hedge ratio is calculated once and it remains constant for the whole investing period. An example of a study that tests a static hedging ratio is a paper by Perold and Schulman (1988). They show that US investors with an internationally diversified portfolio consisting of bonds and equities can decrease the volatility of returns by full currency hedging. They even conclude that hedging can be seen as a free lunch and therefore currency risk should always be hedged fully.

On the other hand there are people that advocate a hedge ratio of zero. Froot (1993) is one of them, he argues that long-term investors should not hedge at all because he finds that in the long run there is no variance reduction anymore; complete hedging increases the variance of a portfolio. Froot's explanation is that exchange rates are mean reverting in the long run and therefore fully hedging is not beneficial.

Another strategy that is proposed is to hedge 50% of the currency risk, also called the regret theory (see Gardner and Wuilloud, 1995). The decision not to hedge or to hedge fully can lead to regret when the wrong decision was taken. Hedging 50% will almost never be optimal in terms of risk and return but regret is minimized by implementing this strategy.

Black (1990) argues that the hedge ratio should be between 0 and 100%. The hedge ratio should be less than 100% because of Jensen's inequality, this is also known as Siegel's paradox. Siegel's paradox is the fact that an exchange rate movement in percent is not the same for a domestic and a foreign investor. The gain on one currency does not equal the loss on the other currency and consequently the hedge ratio should be less than 1. Black states that there is an universal hedge ratio that is equal for all investors in the world because every investor owns a piece of the same international diversified portfolio. His calculations estimate a universal hedge ratio of 77%.

Many other papers investigate the performance of currency hedging for international diversified portfolios. Eun and Resnick (1988) research a volatile exchange rate period (1980-1985) in contrast to earlier studies where there was low volatility and they use an ex-ante instead of an ex-post approach to form efficient stock portfolios. They find that international diversification and hedging improve the Sharpe ratio of portfolios. Abken and Shrikhande (1997) research the hedging effectiveness for stock and bond portfolios separately from 1980 till 1995. For stocks they also find that hedging improves the risk-return relationship for the 1980-1985 period but they do not find confirming results for later time periods. This can be explained by the fact that between 1980 and 1985 there was an appreciation of the dollar against most currencies and after that depreciation till the beginning of the nineties. For bonds the results show that the variance and the returns go down, so it depends on the risk appetite of an investor whether this is an improvement for him or not.

A widely used method to estimate the hedge ratio is by running a regression with spot and forwards returns as dependent and independent variable respectively, the coefficient of the forward rate in the regression gives the hedge ratio. This ordinary least squares (OLS) approach recognizes that the correlation between spot and futures returns is not perfect. A move in the spot exchange rate does not necessarily mean that the futures exchange rate changes with the same magnitude (Ederington, 1979).

All previous mentioned studies use a static hedge ratio, i.e. the hedge ratio does not change during the investment period. The OLS method described above has the shortcoming that it could give bad estimates in times of high volatility. It assumes that correlations and covariances between spot and forward rates are constant and this is not a realistic assumption. It is well known that financial assets exhibit time-varying conditional heteroskedasticity (Lien et al., 2002). It would be better to have a dynamic hedge ratio that changes over time and that takes the current economic situation into account. Therefore many dynamic hedging strategies have been developed; most models are extensions of GARCH models. GARCH models can take time-varying heteroskedasticity into account and are therefore capable to calculate a dynamic hedge ratio.

Engle (1982) and Bollerslev (1987) are the developers of the ARCH and GARCH model. These models have been modified in several ways by different authors. One modification is the multivariate GARCH model VECH, this model was developed by Bollerslev et al. (1988). This model estimates a time-varying variance-covariance matrix, the problem with this model is that the variance-covariance matrix must be positive semidefinite. For instance Lien & Luo (1994) find that it is not unusual that the VECH model violates this assumption. A model that solves this problem is the BEKK model developed by Baba, Engle, Kraft and Kroner (1990). This model ensures that the matrix is positive semidefinite. Some papers tested these models to calculate hedge ratios, Baillie and Myers (1991) is one of them. They compared hedge ratios calculated with a VECH and a BEKK model for commodities. A static hedge ratio calculated with OLS is also employed. They conclude that time-varying hedge ratios give better results than constant hedge ratios. Gagnon et al. (1998) test a trivariate GARCH system for a multicurrency hedging problem and they find that the dynamic hedging ratios provide efficiency and utility gains. A problem with the VECH and the BEKK model is the computational difficultness. A high number of parameters have to be estimated and this can get very complicated for large covariance matrices. Another problem with these models is that the interpretation of the values of the coefficients is not an easy task. Other multivariate GARCH models have been developed that are easier to estimate.

One popular model is the CCC-GARCH (constant conditional correlation) model developed by Bollerslev (1990). In comparison with VECH and BEKK less parameters have to be estimated and therefore it is easier to estimate. Lien et al. (2002) calculate the hedging ratio for different asset classes including currencies and they find that the CCC-GARCH hedge ratios perform worse than the static OLS hedge ratio. On the other hand Kroner & Sultan (1993) also have tested the hedging performance of CCC-GARCH and they find that it gives better results than static hedge ratios estimated with Ordinary Least Squares. They note that the risk reduction is more than enough to offset the higher transaction cost that investors have as a consequence of having a dynamic hedging strategy.

An assumption of CCC-GARCH that is often criticized is the constant correlation assumption. Engle and Sheppard (2001) developed DCC-GARCH (dynamic conditional correlation) which assumes that there are time-varying correlations. Some papers do not test the assumption of dynamic correlation or use methods that are not correct. Tests for constant correlation have been developed by Bera and Kim (1996) and Tse (2000). Tse researches whether there is constant correlation for spot-futures, foreign exchange markets and stock markets and finds that only the last category has dynamic correlation. In this thesis the correlation between forward returns and portfolio returns is investigated.

DCC-GARCH has been used for several purposes, for instance to estimate time-varying correlations between stock markets and foreign exchange markets. A paper that uses DCC-GARCH to calculate hedge ratios for multiple currencies is a paper by Hautsch and Inkmann (2003). From the perspective of an European and an American investor the hedge ratios are calculated for three major foreign currencies and the performance is compared with a full hedging strategy, no hedging at all and hedging 50% (regret theory) of the currency exposure. DCC-GARCH performs best with the full hedging strategy at the second place, performing slightly worse than DCC-GARCH. They use a relatively short sample period of two years (1999-2000) and forecast the hedge ratios one year ahead. They give equal weight to the three countries in the portfolios tested.

Also Zhang (2007) has tested the hedging performance of DCC-GARCH and she compares it with the performance of static OLS hedging and naïve hedging strategies. An equally-weighted portfolio with seven different currencies is constructed and hedged for the time period 2002-2006. DCC-GARCH performs best when there are no restrictions on the hedge. When the hedge is restricted to be between 0 and 1 DCC-GARCH performs best, but it is only slightly better than the performance of naïve hedging strategies. Nevertheless DCC-GARCH with restrictions performs better than static hedging with restrictions.

3. Methodology

In this section the methodology used to form the portfolios and to calculate hedge ratios is described. First the portfolio formation is explained, then the differences between unhedged and hedged portfolio returns and variances are discussed, and then how the portfolio will be hedged. Finally will be explained how the static and dynamic hedge ratios are calculated.

3.1 Portfolio Formation

The hedging effectiveness of different methods is tested by hedging the currency risk of international diversified portfolios with five different methods. Two portfolios will be constructed to test the performance of the hedging strategies. There will be a portfolio consisting of stocks and bonds from developed countries and one portfolio for emerging countries. The portfolios will consist for 60% out of stocks and for 40% out of bonds. This is a method that is also used by many practitioners in reality.

These portfolios are constructed in the following way. First daily percentage returns in dollars and the volatility of country MSCI indices and bond indices are calculated for different time-periods. Then variance-covariance matrices are made to study the interdependence between the indices, between the local currencies and between the indices and the currencies; this will be explained in more detail in the next section. The optimal weights are then computed by maximizing the Sharpe ratio of the portfolio by changing the weights given to the indices. The equation of the Sharpe ratio is:

(1) $$SR_p = \frac{(R_p - R_f)}{\sigma_p}$$

R_p is the return on the optimal portfolio, R_f is the risk-free rate (3-month US Treasury-Bills)[1] and σ_p is the standard deviation of the portfolio. The Sharpe-ratio measures the return in excess of the risk-free rate per unit of risk taken.

There are some constraints given to the weights. To guarantee that every country is in the portfolio a minimum of 10% is invested in every country and to avoid that the remaining weight goes to only one country the maximum weight is 40%.

(2) $$0.1 \leq w_i \leq 0.4$$

[1] US Treasury Bills are chosen because there is no reliable data on risk-free rates in emerging countries. It would be better to use a value-weighted risk-free rate to compute the Sharpe ratio. When for instance 10% is invested in Australia the risk-free weight of Australia would get a weight of 10% in the risk-free rate of the portfolio.

where w_i is the weight given to country i. This is done because the main purpose of this thesis is to analyze the hedging strategies and therefore it is necessary to diversify across multiple countries. By maximizing the Sharpe ratio instead of using an equally weighted method however, there is made sure that the diversification is not only a naïve strategy. The weights given to the countries are constant during the investment period.

3.2 Unhedged Portfolio

There are two sources of risk when investing abroad, namely the volatility of your foreign security returns and the volatility of the foreign exchange rate. In this paper the returns on a security index in local currency are defined as $r_{lt} = 100\ln(p_t/p_{t-1})$, the price of the security index today is denoted by p_t and the price of yesterday is p_{t-1}. The movement of the foreign exchange rate is calculated as $e_t = 100\ln(s_t/s_{t-1})$, the exchange rate of today is denoted by s_t and the exchange rate of yesterday is s_{t-1}. When these two numbers are calculated the dollar return of an unhedged portfolio can be obtained:

(3) $$r_t^U = (1 + r_{lt})(1 + e_t) - 1$$

where r_{lt} is the return in local currency and e_t is the rate of change of the exchange rate. The equation can be approximated with a simpler equation. After some rewriting and removing the product of r_{lt} and e_t because the value of this is very small the returns in dollars are:

(4) $$r_t^U \approx r_{lt} + e_t$$

The variance of an unhedged portfolio consisting of several countries is denoted by the following equation:

(5) $$\sigma_u^2 = \sum_{i=1}^{N}\sum_{j=1}^{N} w_i w_j\, cov(r_i, r_j) + \sum_{i=1}^{N}\sum_{j=1}^{N} w_i w_j\, cov(e_i, e_j) + 2\sum_{i=1}^{N}\sum_{j=1}^{N} w_i w_j\, cov(r_i, e_j)$$

where w_i is the weight given to market i. The unhedged portfolio variance consists of three components: the covariance of the returns on the securities, the covariance of the exchange rates and the covariance between the security returns and the exchange rates. The influence of movements of the exchange rates has a larger (smaller) influence when the correlation between the stock market and the foreign exchange market is higher (lower) because then the third component will be larger.

3.3 Hedging with Forwards

Several alternatives exist to hedge foreign exchange risk. The most used derivatives are futures, forwards and options. Differences between forwards and futures are not very big, the main difference is that futures are mark-to-market; the only payments with forwards are at maturity. Disadvantages of futures with respect to forwards are that the contract size of futures is fixed and therefore it is difficult to hedge the amount of money exactly that you want to hedge, the expiration date often does not expire on the date that you want and there are less future contracts on currencies available in comparison with forwards. On the other hand futures eliminate counter-party risk and they are more easily available.

In this paper foreign exchange risk is hedged with 3-month forward contracts. An investor has to short forward contracts to hedge; this means that he has to sell foreign currency at the end of the contract. In exchange he will get back his local currency. By doing this there is no foreign exchange risk left because the future spot exchange rate became certain by shorting forwards. When the home currency appreciates this means that the return on a foreign investment becomes smaller because the foreign currency depreciates at the same time. By shorting forwards you mitigate this effect and you are insured against an appreciation of the home currency.

The dollar return on a hedged portfolio can be written as:

(6) $$r_t^H \approx r_{lt} - f_t$$

The difference between the unhedged and hedged returns is that the exchange rate movement is replaced by the forward return f_t . This can also be seen in the equation of the variance of an hedged portfolio:

(7) $$\sigma_h^2 = \sum_{i=1}^N \sum_{j=1}^N w_i w_j \, cov(r_i, r_j) + \sum_{i=1}^N \sum_{j=1}^N w_i w_j \, cov(f_i, f_j) - 2 \sum_{i=1}^N \sum_{j=1}^N w_i w_j \, cov(r_i, f_j)$$

where w_i is the weight given to market i. The hedged portfolio variance consists of three components: the covariance of the returns on the securities, the covariance of the forward rates and the covariance between the security returns and the forward returns.

3.4 Static Hedge Ratios

The static and dynamic hedge ratios will be estimated with daily data from January 1998 on with different in-sample periods. This periods are specified in Chapter 4.

Four different static hedge ratios are going to be tested in this paper: a hedge ratio of 100%, 0%, 50% and an hedge ratio estimated with Ordinary Least Squares. The OLS static optimal hedge ratio is the ratio of the position in forwards that minimizes the variance of the portfolio. This optimal hedge ratio for a single currency can be calculated with the following equation.

(8) $$h_i^* = cov(R_i^{uh}, f_i)/var(f_i)$$

h_i^* is the optimal hedge ratio, $R_{i,}^{uh}$ denotes the unhedged return of the optimal portfolio in domestic currency and f_i is the return on a forward contract. It can also be estimated with a regression:

(9) $$R_{i,t}^{uh} = \alpha + \beta f_{i,t} + \varepsilon$$

where the coefficient β gives the optimal hedge ratio for a foreign currency.

3.5 Dynamic Hedge Ratios

Static hedging assumes that variances of and covariances between security returns and foreign exchange rate returns are constant over time. In this paper one dynamic hedging strategy is tested namely CCC-Garch or DCC-Garch. CCC-Garch assumes that the correlation between assets is constant while DCC-Garch assumes that there is dynamic correlation. To check whether the dataset has dynamic correlation a regression developed by Tse (2000) is employed. He defines dynamic correlation as:

(10) $$\rho_{ij,t} = \rho_{ij} + \delta z_{i,t-1} z_{j,t-1}$$

the dependent variable, $\rho_{ij,t}$ is the time-varying correlation; the independent variable $z_{i,t-1} z_{j,t-1}$ is the standardized return (r_t/σ_t) and the coefficient ρ_{ij} is the average correlation estimated with DCC-Garch. When the coefficient δ is significantly different from zero there is dynamic correlation.

When the test result implies that correlation varies over time DCC-GARCH is used instead of CCC-Garch because this model assumes, in contrast with CCC-GARCH, dynamic correlation over time between assets. CCC-Garch does assume that covariances and variances change, this can be seen in equation 11:

(11) $$h_i^* = cov(R_{i,t}^{uh}, f_{i,t})/var(f_{i,t})$$

the hedge ratio changes over time now, the covariances and variances are dependent on *t.* The conditional variance-covariance matrix is estimated with the equation 12, in the case of two assets the equations is as follows:

(12) $$H_t = D_t R D_t$$

(13) $$H_t = \begin{bmatrix} \sqrt{\sigma_{11,t}} & 0 \\ 0 & \sqrt{\sigma_{22,t}} \end{bmatrix} \begin{bmatrix} 1 & \rho_{12} \\ \rho_{21} & 1 \end{bmatrix} \begin{bmatrix} \sqrt{\sigma_{11,t}} & 0 \\ 0 & \sqrt{\sigma_{22,t}} \end{bmatrix}$$

D_t is a matrix with the standard deviations estimated by univariate GARCH on the diagonal and R a matrix with the constant correlation on the diagonal. The time-varying variances are thus estimated by an univariate GARCH model. The returns of the portfolio in domestic currency and the returns on the forwards are the inputs of the GARCH models:

(14) $$\sigma_{i,t}^2 = \omega_i + \sum_{p=1}^{P} \alpha_i e_{i,t-1}^2 + \sum_{q=1}^{Q} \beta_i \sigma_{i,t-1}^2$$

For every forward return serie and for the unhedged portfolio return the variance is calculated with this equation. The parameters ω_i, α_i and β_i are different for the variances of each return series, all parameters must be positive and $\alpha_i + \beta_i$ must be less than 1. So the standard deviation depends on the squared residual $e_{i,t-1}^2$ and the variance $\sigma_{i,t-1}^2$ of yesterday. The parameters are estimated with the maximum likelihood procedure of Marquardt. The covariance between the portfolio return and the forward return can be calculated with:

(15) $$cov_{i,j} = R_{i,j}\left(\sigma_{i,t}/\sigma_{j,t}\right)$$

where $R_{i,j}$ denotes the correlation between the portfolio return and the forward return. The correlation is constant during the whole sample period.

The variance-covariance matrix of DCC-GARCH is slightly different from the one of CCC-Garch:

(16) $$H_t = D_t R_t D_t$$

the correlations are time varying so R has the subcript t now. R_t is a *k x k* time-varying correlation matrix and D_t is a *k x k* diagonal matrix of the time-varying standard deviations. The time-varying correlation can be calculated as follows:

(17) $$\rho_{ij,t} = q_{ij,t}/\sqrt{q_{i,t} q_{j,t}}$$

where $q_{ij,t}$ and $q_{i.t}$ are:

(18) $$q_{ij,t} = \bar{\rho}_{ij} + \alpha\left(\varepsilon_{i,t-1}\varepsilon_{j,t-1} - \bar{\rho}_{ij}\right) + \beta(q_{ij,t-1} - \bar{\rho}_{ij})$$

(19) $$q_{i.t} = 1 + \alpha(\varepsilon_{i,t-1}^2 - 1) + \beta(q_{i,t-1} - 1)$$

where $\bar{\rho}_{ij}$ is the unconditional correlation, $\varepsilon_{i,t-1}\varepsilon_{j,t-1}$ are the standardized residuals. The parameters that have to be estimated are α and β. The correlations are modeled as a GARCH processes with GARCH parameters α and β. In matrix form the equations for the variance-covariance matrix Q_t and the correlation matrix R_t becomes:

(20) $$Q_t = (1 - \sum_m \alpha_m^* - \sum_n \beta_n^*)\bar{Q} + \sum_m \alpha_m^* \ (\varepsilon_{t-m}\varepsilon_{t-m}') + \sum_n \beta_n^* \, Q_{t-n}$$

(21) $$R_t = Q_t^{*-1} Q_t Q_t^{*-1}$$

where $\bar{Q}$ is the unconditional covariance of the standardized residuals estimated with univariate GARCH, α_m^* and β_n^* are the two parameters that have to be estimated. When $\alpha + \beta$ is zero DCC-GARCH reduces to CCC-GARCH. Q_t^{*-1} represents the square root values of the diagonal of the matrix Q_t. Q_t for two assets is:

(22) $$Q_{t+1} = \begin{bmatrix} q_{11,t+1} & q_{12,t+1} \\ q_{12,t+1} & q_{22,t+1} \end{bmatrix}$$

(23) $$Q_{t+1} = \begin{bmatrix} 1 & \rho_{12} \\ \rho_{12} & 1 \end{bmatrix} (1 - \alpha - \beta) + \alpha \begin{bmatrix} \varepsilon_{1,t}^2 & \varepsilon_{1,t}\varepsilon_{2,t} \\ \varepsilon_{1,t}\varepsilon_{2,t} & \varepsilon_{2,t}^2 \end{bmatrix} + \beta \begin{bmatrix} q_{11,t} & q_{12,t} \\ q_{12,t} & q_{22,t} \end{bmatrix}$$

The matrix Q_t^* is:

(24) $$Q_t^* = \begin{pmatrix} \sqrt{q_{11,t}} & 0 \\ 0 & \sqrt{q_{22,t}} \end{pmatrix}$$

Let θ denote the parameters of D_t and φ the parameters of R_t, then the log-likelihood function of DCC-GARCH is:

(25) $$\ell_t(\theta, \varphi) = -(1/2)(\log|D_t R_t D_t| + r_t' \, D_t^{-1} R_t^{-1} D_t^{-1} r_t)$$

This likelihood function can be split into a volatility part and a correlation part. The likelihood function of the volatility part is:

(26) $$\ell_v(\theta) = -(1/2) \sum_{t=1}^{T} \sum_{i=1}^{n} (\log(2\pi) + \log(\sigma_{i,t}^2) + r_{i.t}/\sigma_{i,t})$$

which is the sum of the individual GARCH likelihoods. The second likelihood function is of the correlation part:

(27) $$\ell_C(\theta, \varphi) = -(1/2)(\sum_{t=1}^{T} \log|R_t| + \varepsilon_t' R_t^{-1} \varepsilon_t)$$

So given the maximized value of θ the correlation part φ is maximized with the previous equation. After this step the parameters of DCC-GARCH α and β are obtained and the correlation can now be calculated.[2] If we have the time-varying correlation the values for the time-varying covariance of CCC-GARCH will change. As a consequence of that the time-varying hedge ratios will change.

[2] The parameters are estimated in Matlab using the code of Kevin Sheppard. The code can be found at http://www.kevinsheppard.com/wiki/UCSD_GARCH

4. Data

For all countries, emerging and developed, MSCI indices are used for stocks. For bonds Datastream indices are used for developed countries (consisting of governments bonds with different maturities); JP Morgan's ELMI indices are used for emerging countries and all spot and three-month forward rates against the dollar are obtained from WM Reuters or Thomson Reuters and are downloaded from Datastream. Data for all forward rates is available from 1998 on; the portfolios and hedge ratios are therefore estimated with daily data from 1998. Datacodes can be found in Appendix A.

The portfolio of developed countries is formed with the following economies: Australia, Canada, Sweden, Switzerland and the United Kingdom. The five countries used to form the emerging markets portfolio are: Hungary, Mexico, Poland, South-Africa and Taiwan.[3]

These developed countries are chosen because they are highly correlated with each other. Figure 1 and Table 1 show that there is high correlation between the developed countries spot rates. To make it easier to compare the spot rates in the graph the exchange rates for all countries are set equal to 1 at January 1 1998. In table 1 can be seen that the correlation generally lies around 0,5. Figure 2 and table 2 show that the spot rates are further away from each other for emerging markets and the correlation between the spot rates is lower.

In the case of the developed countries portfolio it is usually easy to predict which hedging strategy will perform best because all the currencies exhibit the same pattern. When all foreign currencies are appreciating against the dollar no hedging should do better than full hedging. How the other methods perform (OLS, CCC-Garch and DCC-Garch) relative to full hedging and no hedging is harder to predict. For emerging countries it is less obvious which hedging strategy will deliver the highest returns. When one currency appreciates the chances are smaller than for developed countries that the other currencies will appreciate too.

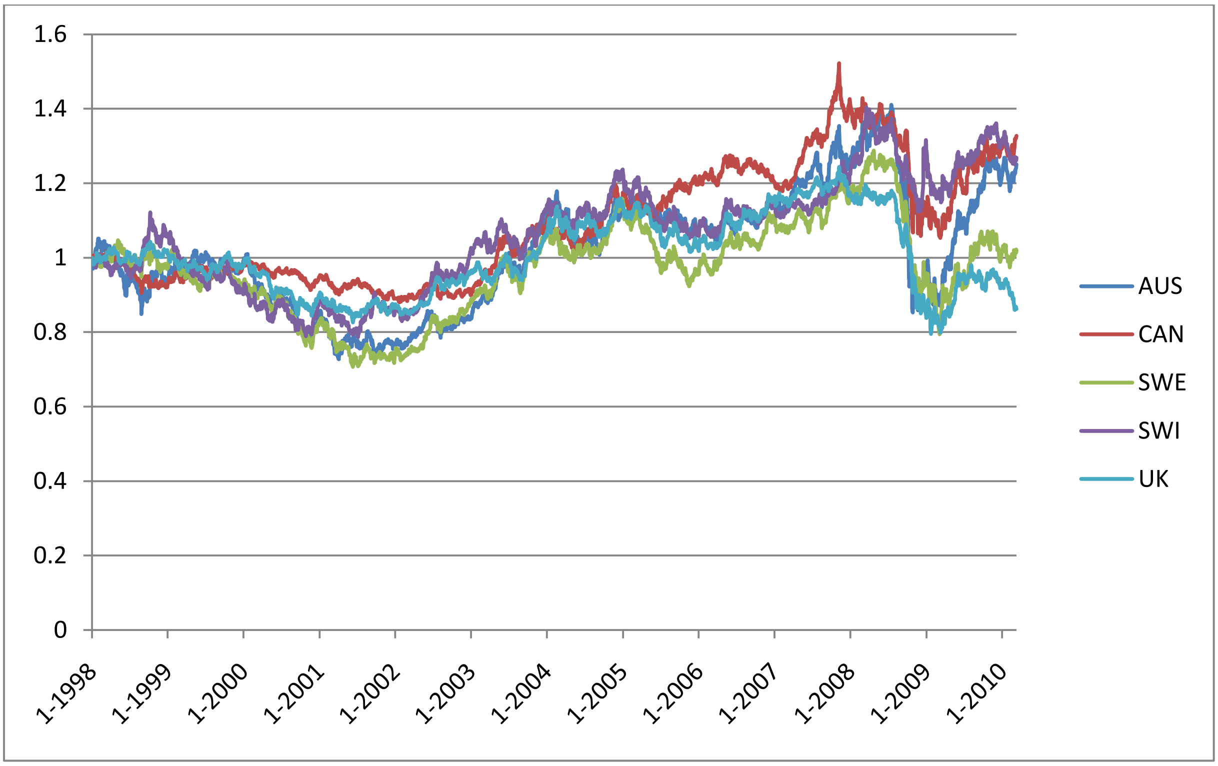
Different in-sample and out-of-sample periods are used to form the portfolios and to evaluate the hedging effectiveness of the strategies.

- Full period: In-sample period runs from 01-01-1998 till 31-12-2004, out-of-sample period from 01-01-2005 till 01-03-2010. In this case the hedging effectiveness is evaluated for the whole sample. There are depreciating and appreciating periods in the out-of-sample period for both emerging and developed markets.

[3] These specific emerging countries are considered as advanced emerging countries by FTSE. Also Brazil belongs to this list but data for forward rates is only available from 2002 on and therefore is chosen not to include Brazil.

- Period 1: In-sample period runs from 01-01-1998 till 31-12-2004, out-of-sample period from 01-01-2005 till 01-07-2008. In this period the dollar depreciated on average against the foreign currencies of developed countries but the magnitude is small. For emerging countries there is no clear pattern.
- Period 2: In-sample period runs from 01-01-1998 till 01-07-2008, out-of-sample period from 01-07-2008 till 01-01-2009. In this period the dollar appreciated against the foreign currencies of developed countries and to a lesser extent against the currencies of emerging countries.
- Period 3: In-sample period runs from 01-01-1998 till 01-01-2009, out-of-sample period from 01-01-2009 till 01-03-2010. In this period the dollar depreciated (with a bigger magnitude than in period 1) against the foreign currencies of developed countries and emerging countries.

Figure 1: Spot exchange rates developed countries



The spot rate is set at a rate of 1 on the first of January 1998. When the spot rate becomes larger than 1 this means that the foreign currency appreciated against the dollar.

Table 1: Correlation between spot exchange rates developed countries 1998-2010

	AUS	CAN	SWE	SWI	UK
AUS	1				
CAN	0.566	1			
SWE	0.572	0.488	1		
SWI	0.397	0.313	0.720	1	
UK	0.511	0.409	0.606	0.586	1

The correlation in the table is the correlation between the daily spot returns of the exchange rate of the countries. The correlation shown is the correlation between 01-1998 – 03-2010.

Figure 2: Spot exchange rates emerging countries

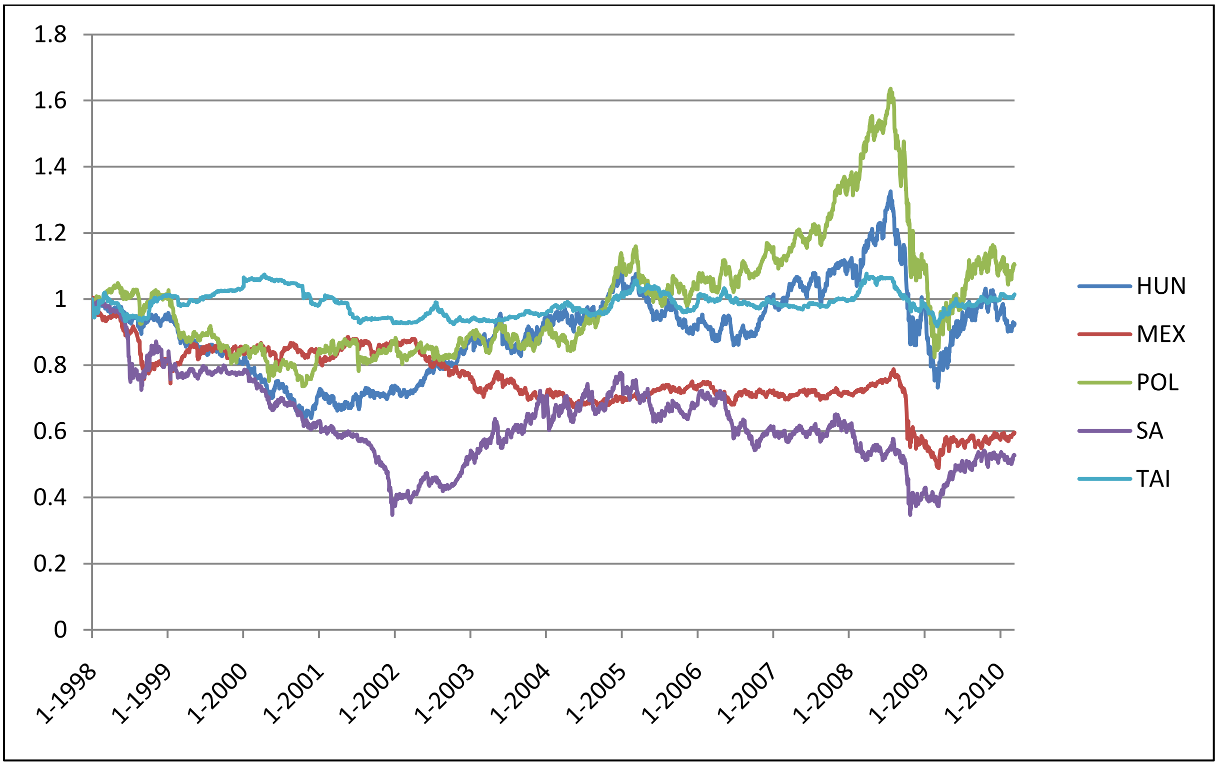


Table 2: Correlation between spot exchange rates emerging countries 1998-2010

	HUN	MEX	POL	SA	TAI
HUN	1				
MEX	0.307	1			
POL	0.692	0.347	1		
SA	0.471	0.400	0.448	1	
TAI	0.201	0.070	0.193	0.129	1

5. Results

In this section first the portfolio weights given to the different countries are shown, then the results of the tests for dynamic correlation are discussed, the hedge ratios that are calculated and finally the performance of the hedging strategies.

5.1 Portfolio Formation

The average returns of the MSCI, bond indices and spot exchange rates for the whole sample are displayed in table 3. In table 4 the portfolio weights of the two different portfolios can be seen of the three in-sample periods. The weights for both stocks and bonds add up to 100%, the proportion invested in stocks is 60% in bonds 40%. A country with low standard deviation and a high return will get a higher weight because the portfolios have a maximized Sharpe ratio. Graphs of MSCI and bond indices and the correlation between the indices can be found in Appendix B and C.

As can be seen in table 3 most returns for stock, bond and spot rates are positive. The highest average stock return in local currency in a developed country can be obtained in Canada; Australia has the second highest but it also has the lowest standard deviation. Because of this Canada and Australia get a lot of weight for stocks in all three samples. For bonds Switzerland gets a lot of weight in all periods, it has the highest return and the lowest standard deviation. Spot returns are positive for all countries which means that the local currency on average appreciated against the dollar. Only the UK has negative spot returns.

There are higher average stock returns in emerging markets except for Taiwan which has negative stock returns and Poland also does not outperform all developed countries. Mexico has the highest stock return for emerging markets and gets the highest weight in all periods. Bond returns are also a lot higher compared with developed countries. Again the highest return is in Mexico but it has also the highest standard deviation; therefore Hungary or Poland get more weight. Spot returns for Mexico and South-Africa are negative; the other countries have slightly appreciating currencies against the dollar.

Table 3: Average returns, stdev., 1998-2010 (annualized)

	AUS	CAN	SWE	SWI	UK
Stock Return	5.05%	5.64%	4.45%	1.01%	0.23%
Stdev.	16.96%	21.28%	27.84%	20.43%	20.41%
Bond Return	-1.01%	0.24%	0.04%	0.23%	0.14%
Stdev.	4.59%	4.26%	3.40%	2.81%	5.37%
Spot Return	2.58%	2.41%	0.91%	2.52%	-0.59%
Stdev.	13.74%	9.19%	11.92%	10.69%	9.26%
	HUN	MEX	POL	SA	TAI
Stock Return	6.28%	13.60%	3.77%	11.22%	-1.83%
Stdev.	31.04%	25.59%	28.77%	22.11%	27.02%
Bond Return	10.57%	12.11%	9.71%	10.32%	2.80%
Stdev.	1.61%	2.10%	1.10%	1.95%	1.90%
Spot Return	0.26%	-3.58%	1.58%	-3.60%	0.12%
Stdev.	14.00%	10.59%	13.62%	18.59%	4.45%

In the table the average daily annualized returns and annualized standard deviation can be seen of returns between 01/01/1998 – 01/03/2010. Returns are annualized with the following formula: $R_p^a = \left(1 + R_p^d\right)^{252} - 1$. The standard deviation is annualized by multiplying the daily standard deviation with the square root of 252.

Table 4: Portfolio weights

Period 1	AUS	CAN	SWE	SWI	UK	HUN	MEX	POL	SA	TAI
Stocks	40%	30%	10%	10%	10%	33%	35%	11%	12%	10%
Bonds	10%	10%	10%	40%	30%	30%	10%	40%	10%	10%
Period 2	AUS	CAN	SWE	SWI	UK	HUN	MEX	POL	SA	TAI
Stocks	30%	40%	10%	10%	10%	21%	40%	19%	10%	10%
Bonds	10%	39%	10%	31%	10%	30%	10%	40%	10%	10%
Period 3	AUS	CAN	SWE	SWI	UK	HUN	MEX	POL	SA	TAI
Stocks	30%	40%	10%	10%	10%	10%	40%	13%	27%	10%
Bonds	10%	30%	10%	40%	10%	30%	10%	40%	10%	10%

In table 4 the weights given to the countries are shown. Sixty percent is invested in stocks, forty percent in bonds. The periods are the periods mentioned in the data chapter so all periods start at 01/01/1998. Period 1 ends at 31/12/2004, period 2 ends at 01/01/2008 and period 3 ends at 01/01/2009.

In table 5 the average returns of the optimal portfolios, average risk-free rates, the standard deviation of the portfolio and the Sharpe ratios are displayed. D1 represents the first developed countries portfolio with an in-sample from 01-01-1998 till 31-12-2004; E1 represents the first portfolio for emerging countries.

As expected the average returns, the standard deviation and the Sharpe ratio are higher in all 3 periods for emerging countries. In one case the Sharpe ratio is negative for developed countries, when data between 01-01-1998 and 31-12-2008 is used. This can be explained by the big impact the financial crisis had on the average stock and bond returns. The standard deviation is the highest in the third period for developed and emerging countries also caused by the financial crisis.

Table 5: Portfolio returns, stdev., Rf., and Sharpe ratio

	D1	D2	D3	E1	E2	E3
Return	5.40%	7.34%	2.94%	9.78%	11.87%	6.60%
Stdev.	9.90%	10.03%	12.77%	13.41%	13.77%	16.12%
Rf	3.23%	3.48%	3.29%	3.23%	3.48%	3.29%
Sharpe Ratio	0.22	0.38	-0.03	0.49	0.61	0.21

The return, standard deviation, risk-free rate and the Sharpe ratio in the table are annualized numbers. For instance 5.40% means that during period 1 an average annual return of 5.40% could have been made.

5.2 Constant or Dynamic Correlation

To test whether there is constant or dynamic correlation the test developed by Tse (2000) is employed. The results of this test can be seen in table 6. Before it can be done first the correlations have to be estimated with DCC-Garch. The parameters of DCC-Garch can be found in appendix D, the correlation over time can be seen in Figure 3. The figure represents the correlation between the forward currency returns of the individual countries and the returns of the portfolio that has a maximized Sharpe ratio over the sample 01/01/1998 – 31/12/2004.

The correlation between the developed countries forward returns and the portfolio returns are higher for developed countries than for emerging countries. The country with the lowest correlation most of the time is Taiwan. This can be explained by the fact that not much weight is put on Taiwan in the portfolio.

Figure 3: Dynamic correlation developed

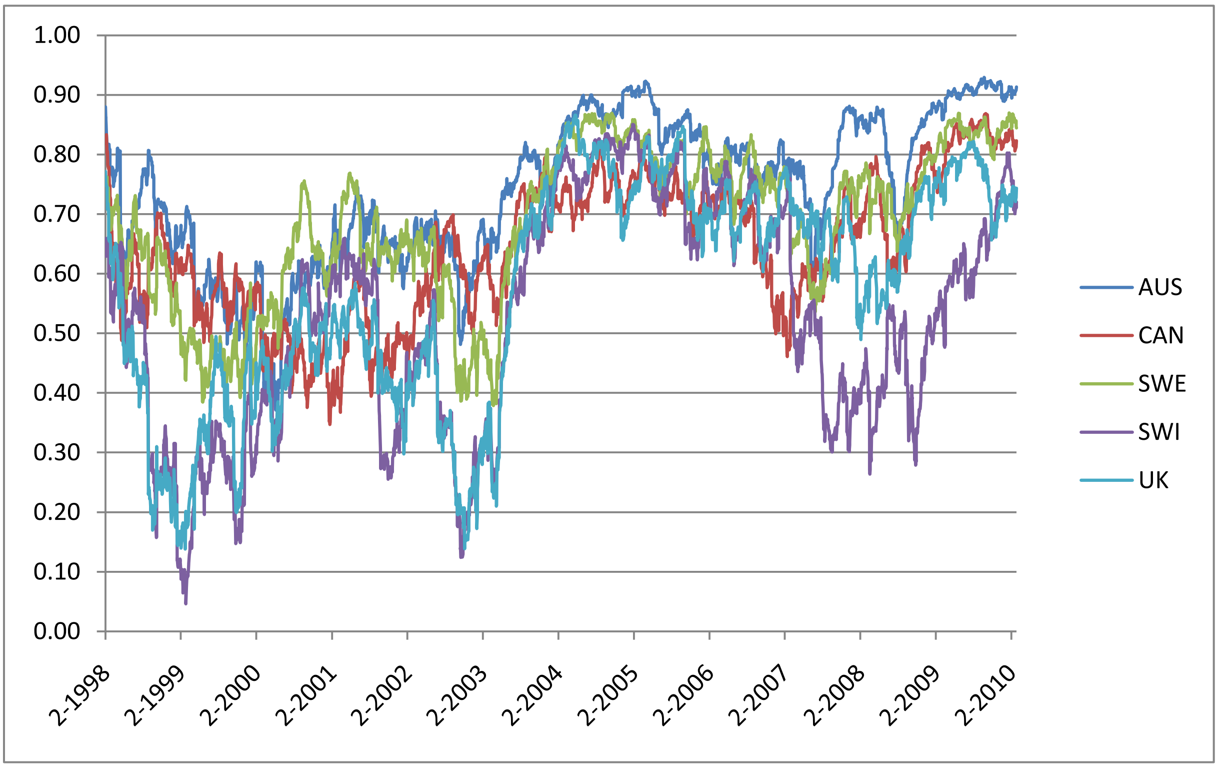
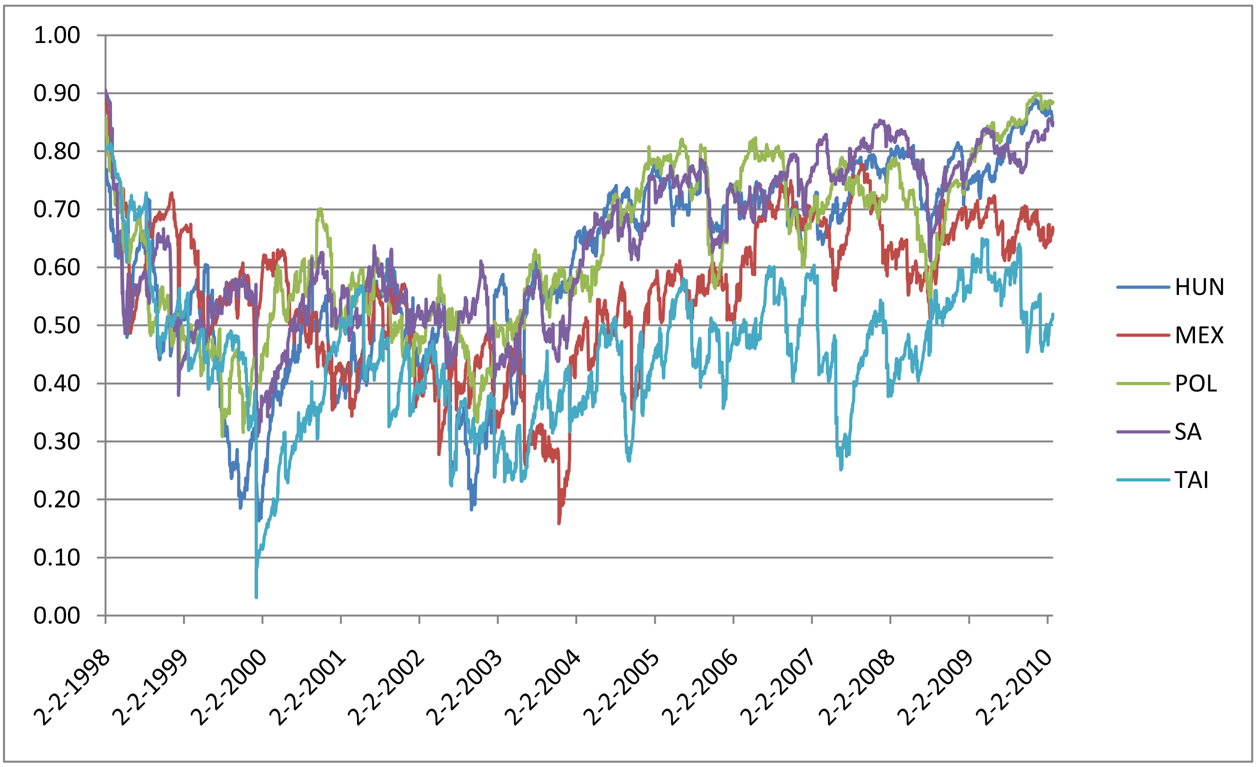


Figure 4: Dynamic correlation emerging



When the dynamic correlation is estimated the test of Tse can be done and the results of the regression are displayed in Table 6.

Table 6: Test results constant correlation

	AUS	CAN	SWE	SWI	UK
Average Correlation ρ	0.827	0.710	0.761	0.595	0.703
Coefficient δ	0.001	0.005	0.002	0.003	0.002
t-value	1.171	3.817	2.478	3.145	3.127
	HUN	MEX	POL	SA	TAI
Average Correlation ρ	0.568	0.538	0.739	0.613	0.248
Coefficient δ	0.002	0.002	0.001	0.001	0.005
t-value	3.755	3.938	2.520	2.915	5.517

The average correlation is the constant of the regression and the coefficient is the coefficient of the standardized returns. The correlation shows the interdependence of the portfolio returns and the forward returns of a country. When the t-value exceeds the critical value of 1.96 the null hypothesis of constant correlation is rejected.

The regression results indicate that all countries except Australia exhibit dynamic correlation between 2005 and 2010. The t-values of the coefficient are significant at a 5% level in all countries so the null-hypothesis of constant correlation is rejected in all cases.

5.3 Hedge Ratios

In this section the hedge ratios calculated with OLS and DCC-Garch will be discussed. In table 6 the hedge ratios of OLS and the average hedge ratios of DCC-Garch is showed. The hedge ratios are constrained between 0 and 1. The average hedge ratios in the table are the ratios for the full sample so from 01-01-2004 till 01-03-2010. Hedge ratios for the three subsamples can be found in Appendix E and F.

Table 7: Hedge ratios

	AUS	CAN	SWE	SWI	UK	HUN	MEX	POL	SA	TAI
OLS	0.54	0.72	0.56	0.36	0.48	0.35	0.56	0.54	0.27	0.51
DCC	0.76	0.69	0.80	0.90	0.86	0.82	0.96	0.96	0.68	0.88

The hedge ratios for OLS and DCC are constrained between 0 and 1. The reported hedge ratios for DCC-Garch are average numbers.

As can be seen in the table the hedge ratios of developed countries and emerging countries have a comparable magnitude and the ratios of DCC-Garch are generally a bit higher than the ratios of OLS.

An explanation for the higher values is that different time samples have been used for both methods to calculate the ratios. OLS uses data between 1998 and 2005 and DCC-Garch uses data from 2005 till 2010. The test in the previous section already showed that there is no constant correlation and this causes differences between OLS and DCC-Garch because OLS assumes constant correlation. Something that contributes to the high average value of DCC-Garch ratios is that for some countries the ratio is 1 for long periods. In figure 3 and 4 the time-varying hedge ratios are shown. Without constraint the hedge ratios of DCC-Garch would be higher than 1 several times. Especially Mexico and Poland have a hedge ratio of 1 almost all the time because of the constraint.

Figure 5: Hedge ratios developed countries

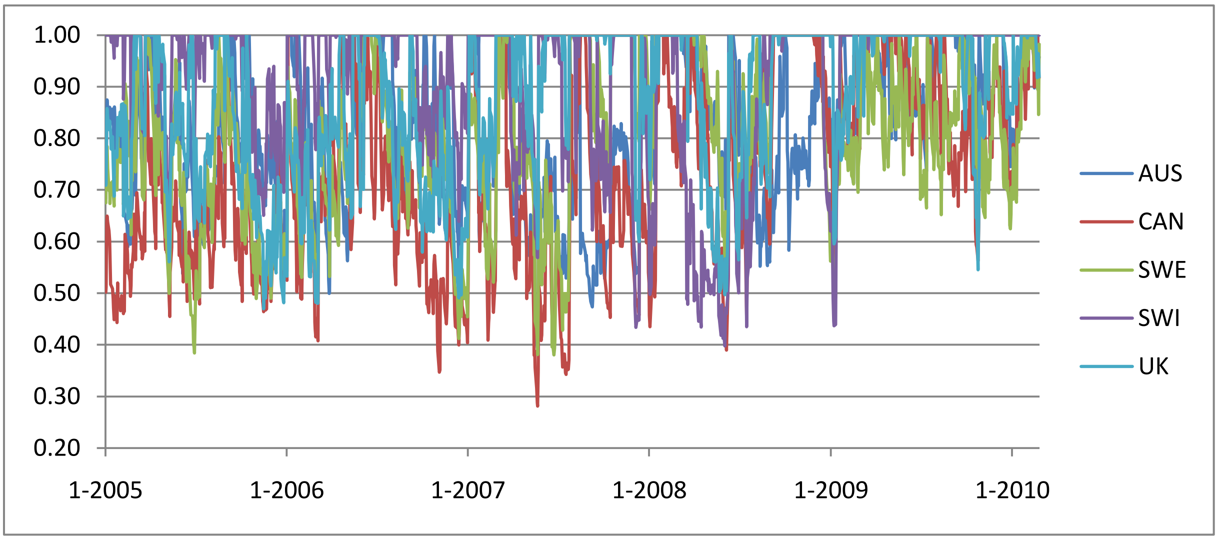
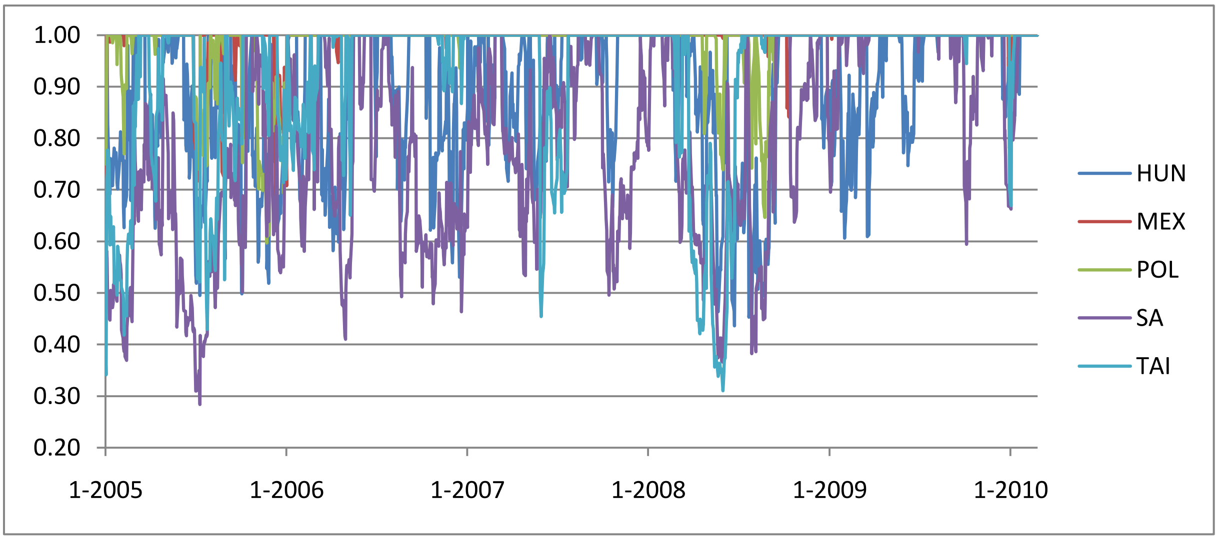


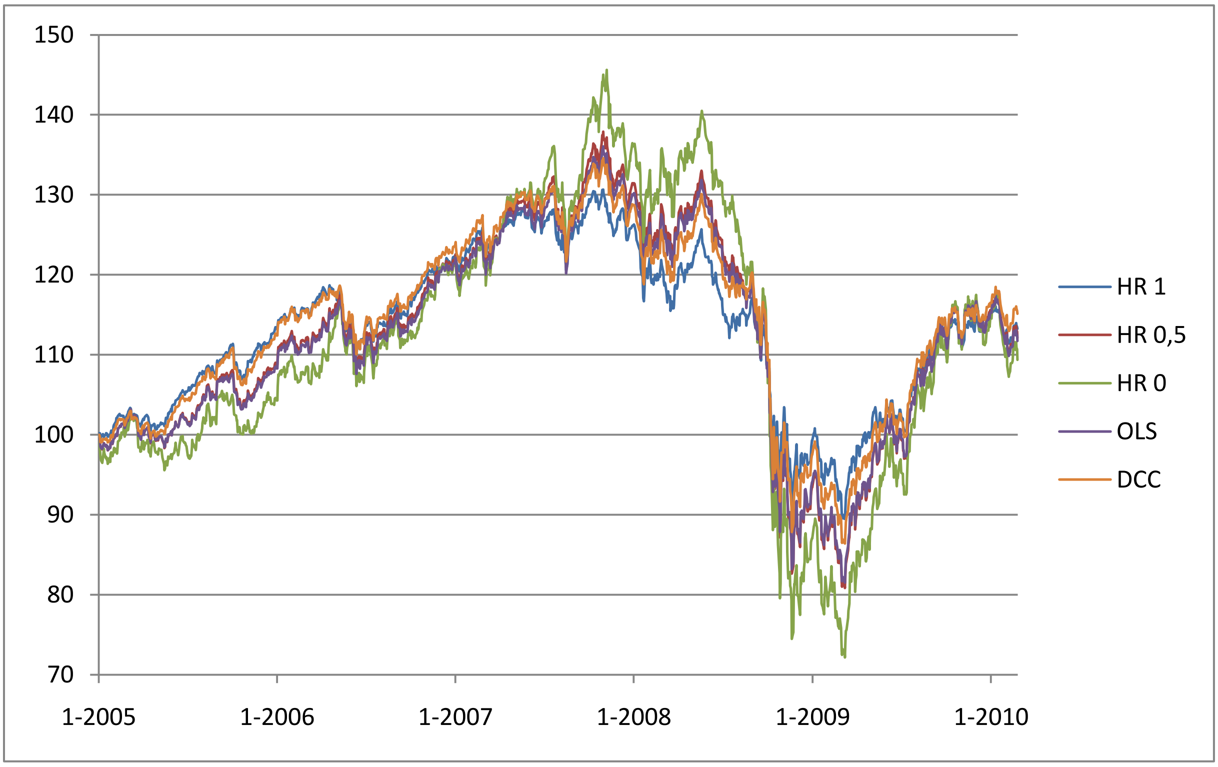
Figure 6: Hedge ratios emerging countries



5.4 Performance Hedging Strategies

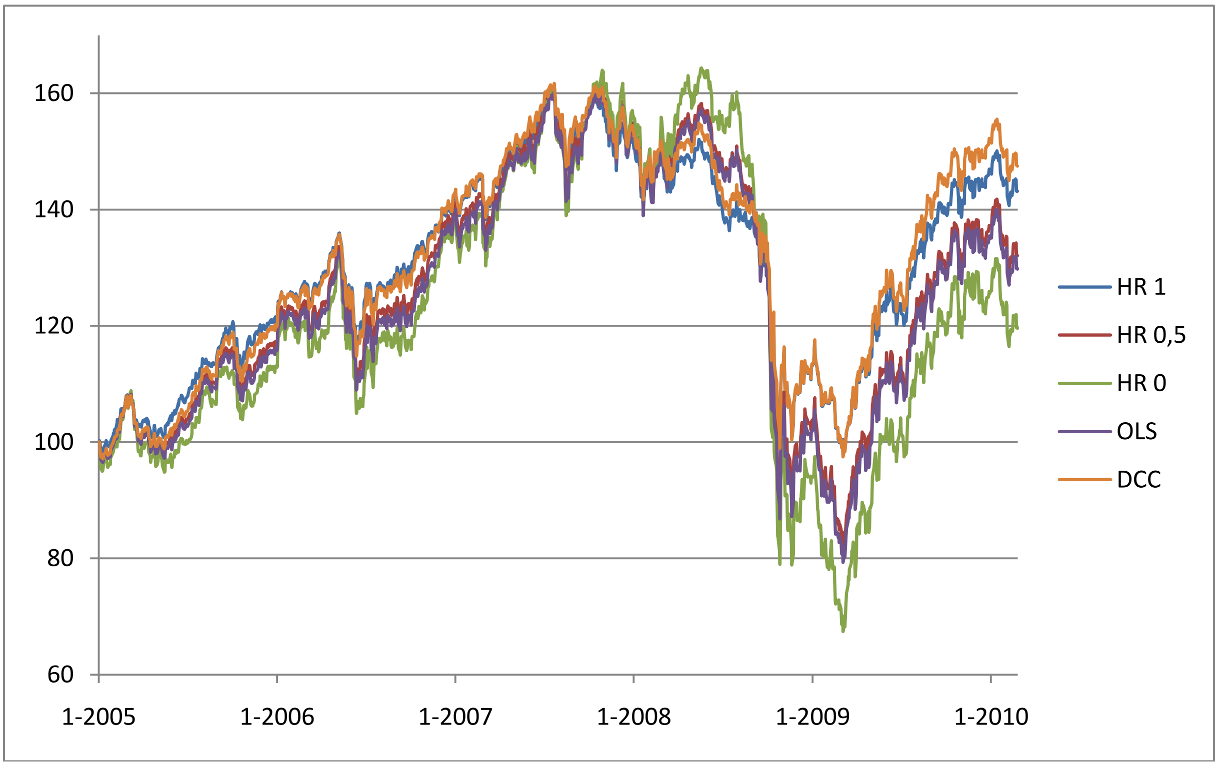
In this section the results of investing according to the weights showed in section 5.1 and hedging following the hedge ratios described in section 5.3 are discussed. In figures 7 and 8 the performance of the portfolio of developed countries and the portfolio of emerging countries can be seen, hedged by different hedging strategies. For every hedging strategy 100 is invested at the beginning of the sample. Only the graphs of the whole sample are reported, the tables give results for all different samples. Graphs for the other periods are in Appendix G.

Figure 7: Performance portfolio developed countries



In the figures can be seen that both portfolios have a higher value than 100 for all hedging strategies in March 2010. The differences are not very big between the hedging strategies; DCC-Garch gave the highest return, almost 15%. The tables will provide a better insight in which hedging strategy performed best considering the return and the standard deviation of the portfolio. The maximum value of the portfolio was getting close to 150 with no hedging at all but then the financial crisis took place which let the value of the portfolio decrease dramatically, no matter what hedging strategy is used. In the beginning of 2009 values of 75 were reached, so that would be a negative investing result after four years.

Figure 8: Performance portfolio emerging countries



Investors would have made higher returns if they invested in emerging markets. DCC-Garch would have given a return of 47% after a bit more than 5 years; no hedging at all gave a return of almost 20%. This is still better than the best performing strategy of developed countries.

In table 8 the annualized return, standard deviation, the return divided by the standard deviation and the Sharpe ratio are reported for all four samples. First the developed markets will be discussed. The highest return can be obtained with DCC-Garch but the standard deviation is higher than of full hedging. For the whole sample DCC-Garch performed best when looking at the Sharpe ratio, full hedging performs best when looking at the risk-adjusted performance and no hedging did worst for both measures. For the first sample period no hedging has the highest Sharpe ratio; this is a period in which the dollar is depreciating. In the third sample period DCC-Garch has the highest Sharpe ratio. Especially this period is a period in which the dollar is depreciating. In the second period full hedging performs best, this is the period in which the dollar is appreciating. The other strategies perform more or less the same. The standard deviation of full hedging is the lowest in all samples, this was to be expected because the aim of hedging is to diversify currency risk away and this causes a lower standard deviation.

Table 8: Evaluation hedging strategies developed

D	01/05-02/10	HR 1	HR 0,5	HR 0	OLS	DCC
	Average Return	2.36%	2.16%	1.69%	2.10%	2.68%
	Stdev	9.60%	12.92%	17.24%	12.50%	10.93%
	Mean/Stdev	0.25	0.17	0.10	0.17	0.24
	Sharpe Ratio	-0.03	-0.04	-0.06	-0.05	0.00
D1	01/05-06/08	HR 1	HR 0,5	HR 0	OLS	DCC
	Average Return	4.42%	6.21%	7.90%	6.00%	5.55%
	Stdev	6.55%	8.28%	10.97%	8.06%	7.19%
	Mean/Stdev	0.67	0.75	0.72	0.74	0.77
	Sharpe Ratio	0.10	0.30	0.38	0.28	0.25
D2	07/08-12/08	HR 1	HR 0,5	HR 0	OLS	DCC
	Average Return	-30.20%	-43.84%	-55.27%	-39.89%	-38.77%
	Stdev	21.74%	28.60%	36.84%	26.10%	25.68%
	Mean/Stdev	-1.39	-1.53	-1.50	-1.53	-1.51
	Sharpe Ratio	-1.43	-1.56	-1.52	-1.56	-1.55
D3	01/09-02/10	HR 1	HR 0,5	HR 0	OLS	DCC
	Average Return	11.79%	16.73%	21.41%	13.45%	14.97%
	Stdev	10.08%	14.41%	19.79%	12.01%	11.40%
	Mean/Stdev	1.17	1.16	1.08	1.12	1.31
	Sharpe Ratio	1.16	1.15	1.07	1.11	1.30

The returns in the table are the average annualized daily returns, the standard deviation is also annualized. HR 1 means a full hedging strategy, HR 0,5 are the results for regret theory and HR 0 is no hedging at all. The start and end of the period is shown for each period, for instance 01/05-06/08 means that the sample periods starts at January 2005 and ends in June 2008.

For emerging countries again DCC-Garch gives the best Sharpe ratio when looking at the full sample. In the full sample period the Sharpe ratio is -0.16 while the second best performing full hedging strategy has a Sharpe ratio of -0.18. Also in the third sub period, the depreciating dollar period, DCC-Garch performs best. In the second period, the appreciating dollar period, full hedging performs best for every measure. Also in the first period full hedging gives the highest Sharpe ratio because it has the lowest standard deviation.

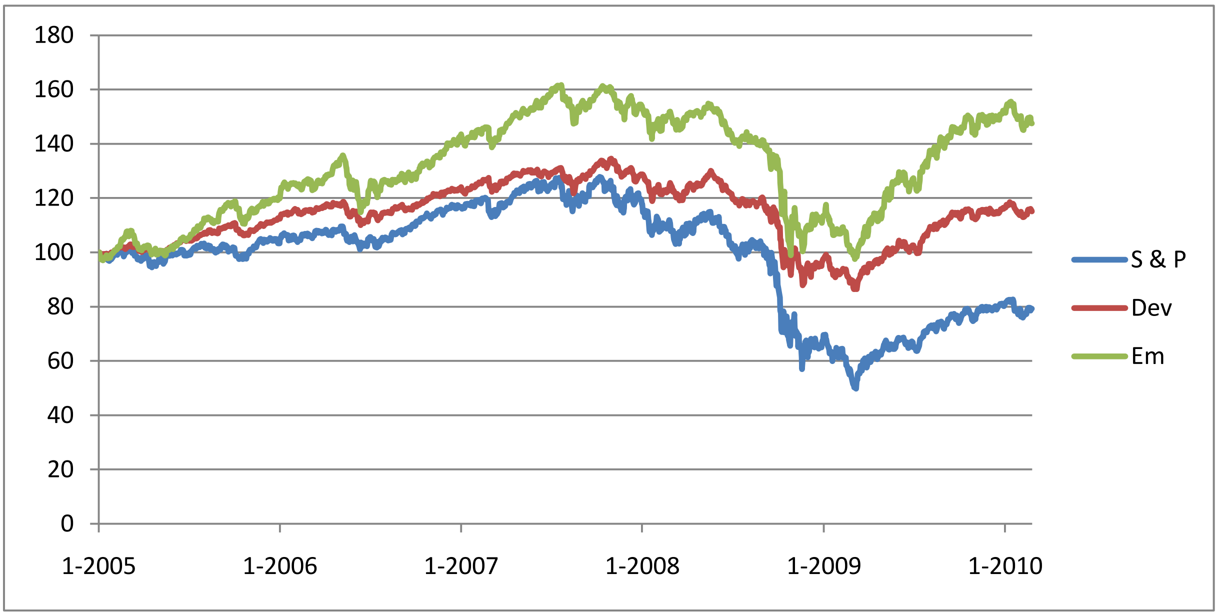
When we compare the developed countries portfolio and the emerging countries portfolio we see that in both cases for the full sample DCC-Garch gives the highest Sharpe ratio. Also in the third period DCC-Garch gives the best results in both cases. In the second period full hedging performs best for both only in the first period there is a difference in the results. For developed countries no hedging performs best, for emerging countries full hedging. The first period is the sub period with the least clear pattern, for developed countries the dollar depreciates slightly against the foreign currencies. For emerging countries there are some appreciating currencies and some depreciating currencies.

Table 9: Evaluation hedging strategies emerging

E	01/05-02/10	HR 1	HR 0,5	HR 0	OLS	DCC
	Average Return	0.26%	-3.35%	-7.12%	-3.94%	0.31%
	Stdev	13.67%	17.19%	21.62%	17.82%	14.40%
	Mean/Stdev	0.02	-0.19	-0.33	-0.22	0.02
	Sharpe Ratio	-0.18	-0.35	-0.45	-0.37	-0.16
E1	01/05-06/08	HR 1	HR 0,5	HR 0	OLS	DCC
	Average Return	18.86%	18.53%	18.02%	18.14%	19.21%
	Stdev	9.61%	11.45%	14.09%	11.78%	10.21%
	Mean/Stdev	1.96	1.62	1.28	1.54	1.88
	Sharpe Ratio	1.69	1.39	1.09	1.31	1.62
E2	07/08-12/08	HR 1	HR 0,5	HR 0	OLS	DCC
	Average Return	-32.66%	-48.76%	-61.50%	-45.76%	-38.87%
	Stdev	25.64%	33.40%	42.66%	32.26%	28.94%
	Mean/Stdev	-1.27	-1.46	-1.44	-1.42	-1.34
	Sharpe Ratio	-1.38	-1.54	-1.50	-1.50	-1.44
E3	01/09-02/10	HR 1	HR 0,5	HR 0	OLS	DCC
	Average Return	17.48%	19.67%	21.29%	19.32%	20.80%
	Stdev	13.32%	18.76%	25.03%	16.72%	15.49%
	Mean/Stdev	1.31	1.05	0.85	1.16	1.34
	Sharpe Ratio	1.11	0.91	0.74	1.00	1.17

When the returns of the portfolio are compared with the returns of the S & P 500 in the same period it is immediately clear that investing in the diversified portfolio would have been a better option. In Figure 9 can be seen that an international diversified portfolio hedged with DCC-Garch has a much better performance than the S&P 500. When 100 was invested in the beginning of 2005 a negative return would have been made after more than 4 years. So diversifying internationally in this case shows to pay-off. Also other hedging strategies or no hedging at all would have given higher returns than the S&P 500.

Figure 9: Comparison S&P 500 performance with portfolios



Dev represents the portfolio of developed countries hedged with DCC-Garch the same goes for Em.. One hundred is invested at January 1 2005.

6. Conclusion

This thesis has examined the hedging effectiveness of different hedging strategies for an internationally diversified portfolio held by an US investor. Two portfolios are formed, one for developed and one for emerging countries, by maximizing the Sharpe ratio of the portfolios. Five different methods have been tested: full hedging, no hedging, regret theory, OLS hedging and DCC-Garch hedging. The hedging effectiveness is tested for different periods and is evaluated by looking at the return, standard deviation, risk-adjusted return and Sharpe ratio of the portfolio.

The results show that for both developed and emerging markets DCC-Garch performs best during the whole period. However, when looking at subsamples DCC-Garch is not always the best choice, there are mixed results. For developed countries in the whole sample DCC-Garch hedging would give the highest Sharpe ratio and also in a clearly depreciating dollar period. In an appreciating dollar period full hedging performs best and in another period in which the dollar depreciates no hedging gives the highest Sharpe ratio. There is one difference in the results in the case of emerging markets namely that in the first period no hedging performs best while full hedging performs best for developed countries. This difference can be explained by the fact that there are some depreciating currencies as well in the first period for emerging countries.

The results suggest using DCC-Garch because in the long run it is the best strategy. For specific time intervals other methods perform best but this time intervals are chosen with backward looking information. In reality it is very hard to predict the course of exchange rates; the random walk model is still the best performing model with respect to forecasting the exchange rate. So for a portfolio manager that wants to hedge currency risk DCC-Garch is an opportunity to get better performance.

It has to be noted that this thesis ignores transaction costs and assumes that daily rebalancing takes place. Transaction cost can influence the results especially because of the daily rebalancing. A suggestion for further research is to take this into account.

References

Abken, P.A. and Shrikhande, M.M., 1997, The role of currency derivatives in internationally diversified portfolios, *Economic Review*, Federal Reserve Bank of Atlanta,34-59.

Baba, Y., Engle, R.F., Kraft, D., and Kroner, K., 1990, Multivariate Simultaneous Generalized ARCH, *unpublished manuscript*.

Baillie, R.T., & Myers, R.J., 1991, Bivariate GARCH estimation of the optimal futures hedge, *Journal of Applied Econometrics* 6, 109 – 124.

Bera, A.K.& Kim, S., 1996, Testing Constancy of Correlation with an Application to International Equity Returns, Center for International Business Education and Research (CIBER) *Working Paper 96-107.*

Black, F., 1990, Equilibrium exchange rate hedging, *Journal of Finance* 45, 899-907.

Bollerslev, T., Engle, R.F., & Wooldridge, J.M., 1988, A capital asset pricing model with time-varying covariances, *Journal of Political Economy*, 96, 116 - 131.

Bollerslev, T., 1987, A Conditional Heteroskedastic Time Series Model for Speculative Prices and Rates of Return, *Review of Economics and Statistics*, 69, 542-547.

Bollerslev, T., 1990, Modelling the Coherence in Short-Run Nominal Exchange Rates: A Multivariate Generalized ARCH Model, *Review of Economics and Statistics*, 72, 498 - 505.

Ederington L.H., 1979, The hedging performance of the new futures markets, *Journal of Finance* 34 , pp. 157–170.

Engle, R., 2002, Dynamic conditional correlation: a simple class of multivariate generalized autoregressive conditional heteroskedasticity model, *Journal of Businessand Economic Statistics* 20, 339-350.

Engle, R., & Kroner, K. , 1995, Multivariate simultaneous generalized ARCH, *Econometric Theory* 11, 122-150.

Engle, R. and Sheppard, K., (2001), Theoretical and Empirical properties of Dynamic Conditional Correlation Multivariate GARCH*, NBER Working Paper 8554*.

Eun, C., and Resnick, B., 1988, Exchange rate uncertainty, forward contracts and international portfolio selection, *Journal of Finance* 43, 197-216.

Froot, K., 1993, Currency hedging over long horizons, *NBER Working Paper* 4355.

Gardner, G., and Wuilloud, T., 1995, Currency risk in international portfolios: How satisfying is optimal hedging? *Journal of portfolio management* 21, 59-67.

Gagnon, L., & Lypny, G., 1995, Hedging Short-Term Interest Risk under Time-Varying Distribution, *The Journal of Futures Markets* 15, 767-783.

Hautsch, N., & Inkmann, J., 2005, Optimal hedging of the currency exchange risk exposure of dynamically balanced strategic asset allocations, *Journal of Asset Management* 4, 173-189.

Kroner, K.F., & Sultan, J., 1993, Time Varying Distribution and Dynamic Hedging with Foreign Currency Futures, *Journal of Financial and Quantitative Analysis* 28, 535 – 551.

Lien, D. & Luo, X. 1994, Multiperiod Hedging in the Presence of Conditional Heteroskedasticity", *Journal of Futures Markets* 14, 927 – 955.

Lien, D. , Tse, Y.K. and Tsui, A.K.C., 2002, Evaluating the hedging performance of the constant-correlation GARCH model, *Applied Financial Economics* 12, 791-798.

Perold, A., & Schulman, E., 1988, The free lunch in currency hedging: Implications for investment policy and performance standards, *Financial Analysts Journal* 44, 45-50.

Solnik, B.H., 1974, An Equilibrium Model of the International Capital Market, *Journal of Economic Theory*, 500-524.

Tse, Y.K., 2000, A Test for Constant Correlations in a Multivariate GARCH Model, *Journal of Econometrics,* 107-127.

Zhang, W., 1997, Dynamic currency risk hedging , *Unpublished paper.*

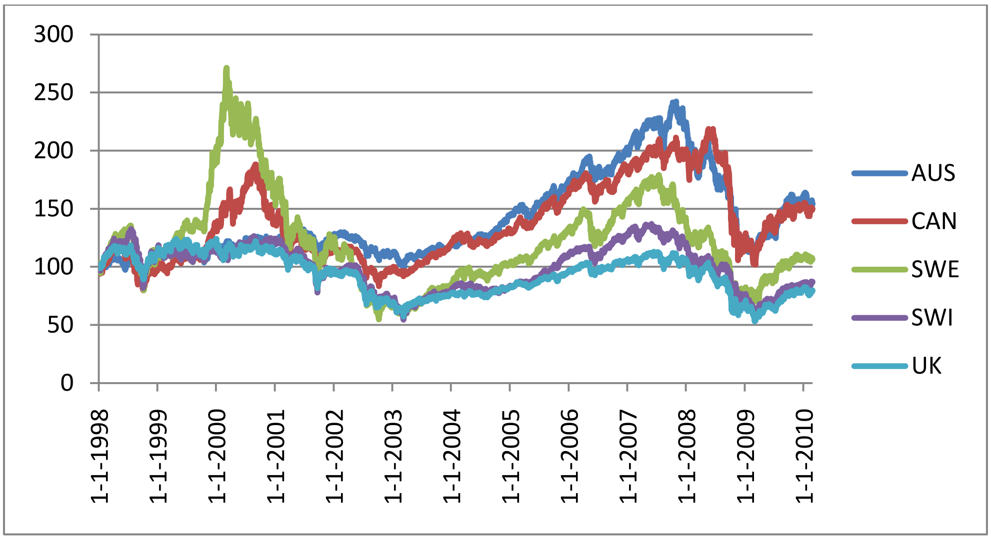
Appendix

Appendix A: Data Codes

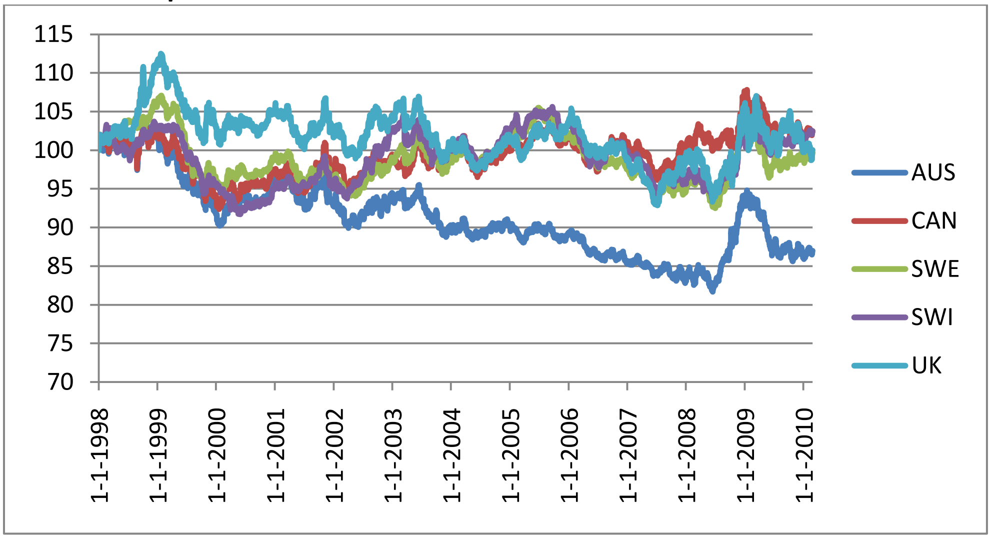
Country	Currency	Spot	Forward	MSCI	Bond
Australia	Australian dollar	AUSTDO$	USAUD3F	MSAUSTL	ASWGVAL
Canada	Canadian dollar	CNDOLL$	USCAD3F	MSCNDAL	AAUGVAL
Sweden	Swedish krona	SWEKRO$	USSEK3F	MSSWDNL	ACNGVAL
Switzerland	Swiss franc	SWISSF$	USCHF3F	MSSWITL	AUKGVAL
UK	British pound	USDOLLR	USGBP3F	MSUTDKL	AJPGVAL
Hungary	Hungarian Forint	TDHUFSP	USHUF3F	MSHUNGL	JPMPHNL
Mexico	Mexican Peso	TDMXNSP	USMXN3F	MSMEXFL	JPMPMXL
Poland	Polish Zloty	TDPLNSP	TDPLN3F	MSPLNDL	JPMPPOL
South Africa	South African Rand	TDZARSP	TDZAR3F	MSSARFL	JPMPSAL
Taiwan	Taiwanese Dollar	TDTWDSP	USTWD3F	MSTAIWL	JPMPTAL

Appendix B: Graphs MSCI and Bond Indices

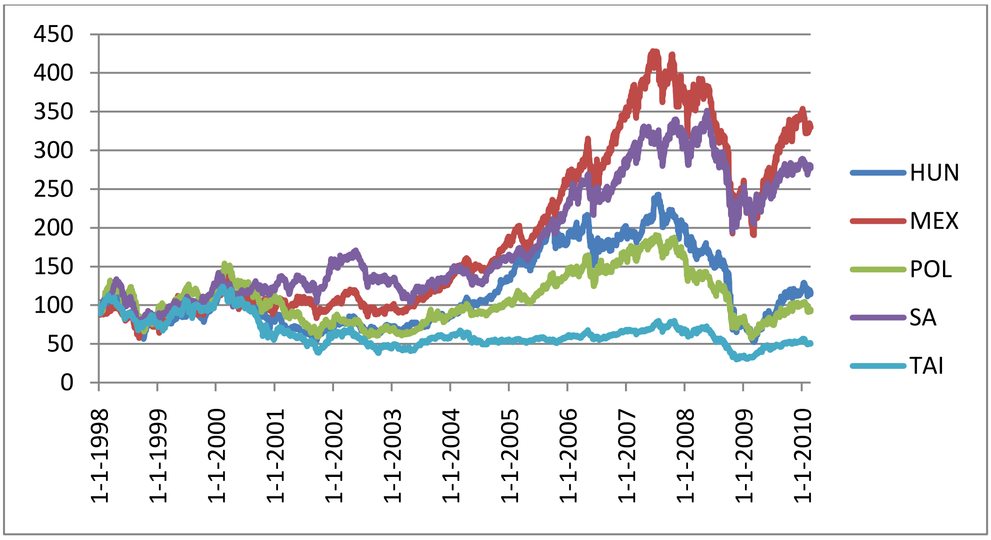
MSCI Developed



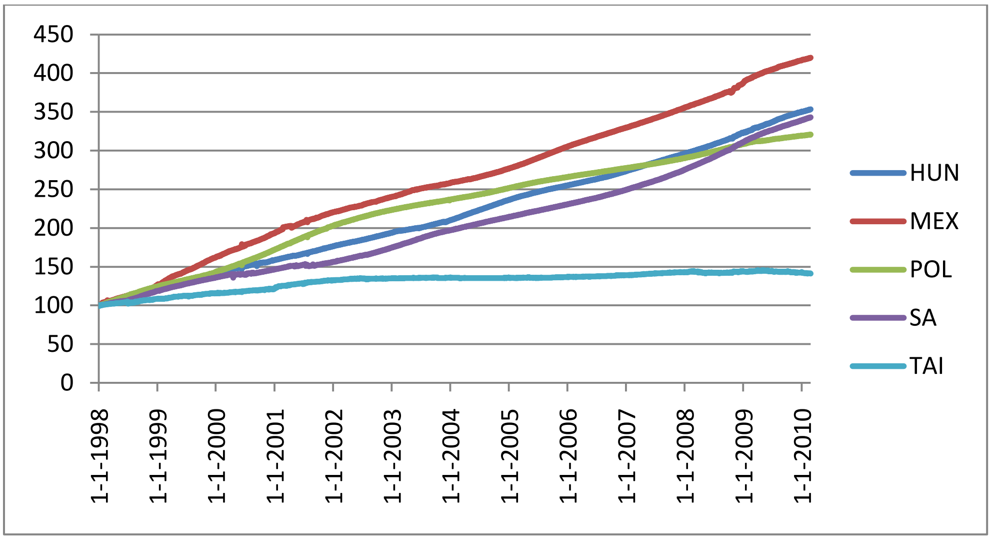
Bonds Developed



MSCI Emerging



Bonds Emerging



Appendix C: Correlation Tables

Correlation MSCI-indices Developed

	AUS	CAN	SWE	SWI	UK
AUS	1.000				
CAN	0.175	1.000			
SWE	0.291	0.444	1.000		
SWI	0.295	0.437	0.683	1.000	
UK	0.306	0.482	0.729	0.806	1.000

Correlation Bond-indices Developed

	AUS	CAN	SWE	SWI	UK
AUS	1.000				
CAN	0.127	1.000			
SWE	0.301	0.398	1.000		
SWI	0.340	0.300	0.549	1.000	
UK	0.207	0.436	0.584	0.473	1.000

Correlation MSCI-indices Emerging

	HUN	MEX	POL	SA	TAI
HUN	1.000				
MEX	0.335	1.000			
POL	0.512	0.291	1.000		
SA	0.450	0.369	0.431	1.000	
TAI	0.187	0.130	0.245	0.284	1.000

Correlation Bond-indices Emerging

	HUN	MEX	POL	SA	TAI
HUN	1.000				
MEX	0.083	1.000			
POL	0.443	0.078	1.000		
SA	0.119	0.044	0.108	1.000	
TAI	0.069	0.208	0.105	0.042	1.000

Appendix D: Parameters DCC-Garch

		D1	D2	D3
AUS	ω	0.000	0.000	0.000
	α	0.062	0.060	0.071
	β	0.903	0.918	0.915
CAN	ω	0.000	0.000	0.000
	α	0.059	0.053	0.059
	β	0.931	0.941	0.939
SWE	ω	0.000	0.000	0.000
	α	0.045	0.038	0.049
	β	0.917	0.923	0.933
SWI	ω	0.000	0.000	0.000
	α	0.027	0.037	0.044
	β	0.896	0.938	0.942
UK	ω	0.000	0.000	0.000
	α	0.055	0.048	0.055
	β	0.900	0.921	0.927
RET	ω	0.000	0.000	0.000
	α	0.082	0.086	0.097
	β	0.855	0.868	0.874
	A	0.014	0.012	0.012
	B	0.979	0.985	0.985

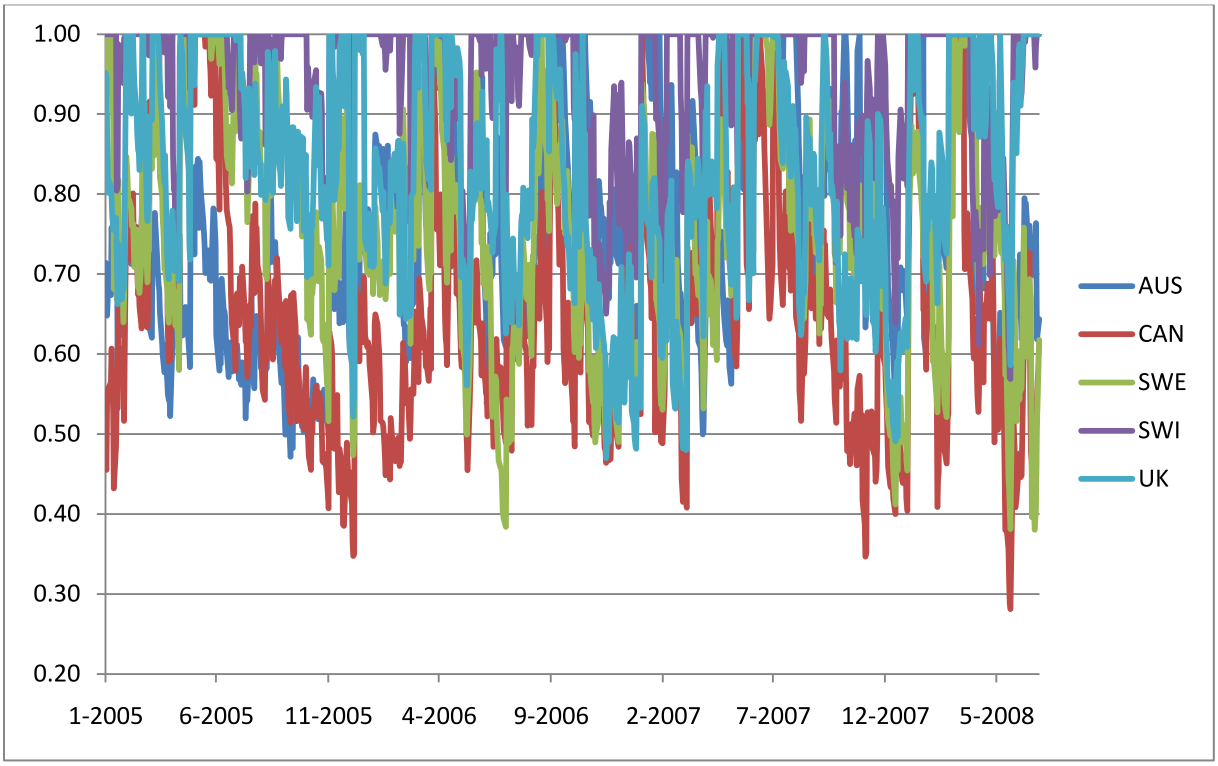
		E1	E2	E3
HUN	ω	0.000	0.000	0.000
	α	0.059	0.050	0.055
	β	0.924	0.932	0.935
MEX	ω	0.000	0.000	0.000
	α	0.190	0.165	0.157
	β	0.693	0.747	0.796
POL	ω	0.000	0.000	0.000
	α	0.125	0.086	0.096
	β	0.786	0.855	0.866
SA	ω	0.000	0.000	0.000
	α	0.116	0.092	0.103
	β	0.884	0.908	0.897
TAI	ω	0.000	0.000	0.000
	α	0.273	0.216	0.220
	β	0.727	0.761	0.766
RET	ω	0.000	0.000	0.000
	α	0.162	0.122	0.144
	β	0.744	0.804	0.802
	A	0.013	0.010	0.011
	B	0.955	0.984	0.983

Appendix E: Hedge Ratios All Periods

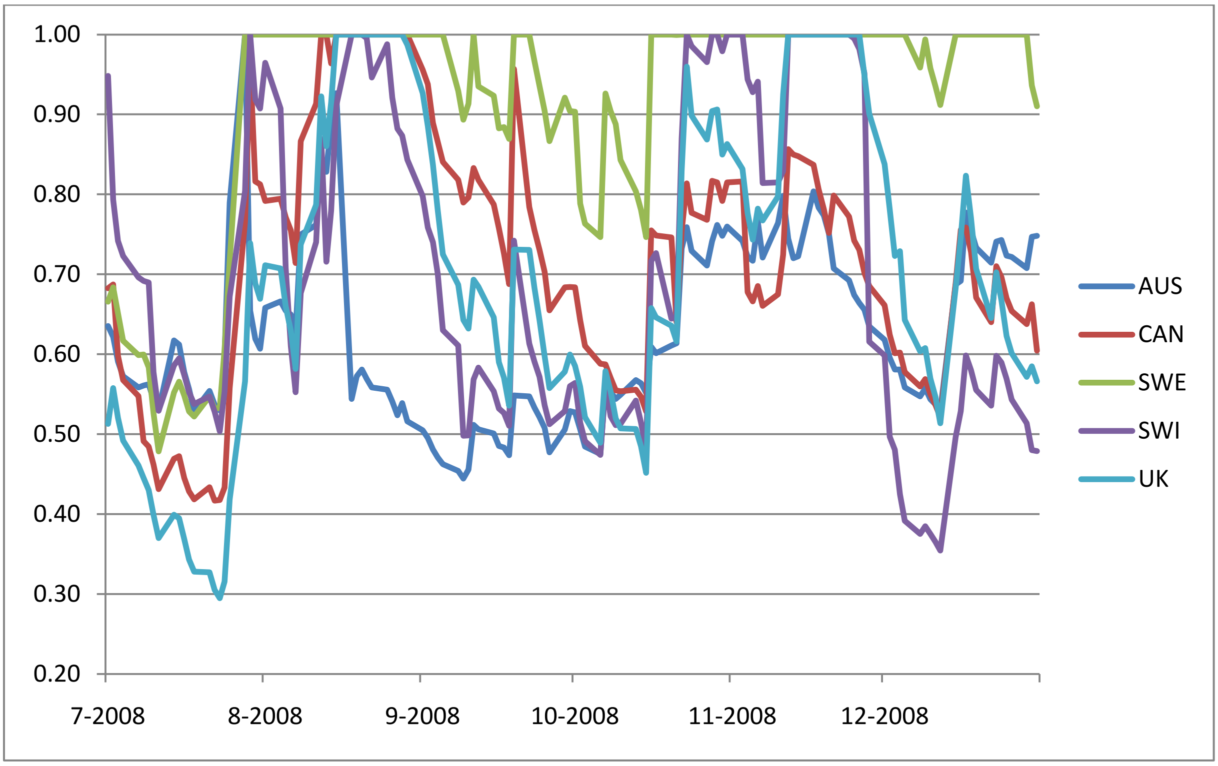
Period 1	AUS	CAN	SWE	SWI	UK	HUN	MEX	POL	SA	TAI
OLS	0.54	0.72	0.56	0.36	0.48	0.35	0.56	0.54	0.27	0.51
DCC	0.75	0.65	0.76	0.94	0.83	0.79	0.94	0.95	0.62	0.86
Period 2	AUS	CAN	SWE	SWI	UK	HUN	MEX	POL	SA	TAI
OLS	0.58	0.84	0.57	0.34	0.50	0.49	0.68	0.67	0.37	0.54
DCC	0.63	0.72	0.91	0.71	0.70	0.94	1.00	0.93	0.51	0.69
Period 3	AUS	CAN	SWE	SWI	UK	HUN	MEX	POL	SA	TAI
OLS	0.67	0.99	0.69	0.41	0.70	0.63	0.76	0.77	0.52	0.70
DCC	0.82	0.87	0.86	0.61	0.82	0.75	0.96	0.82	0.65	0.84

Appendix F: Figures Hedge Ratios

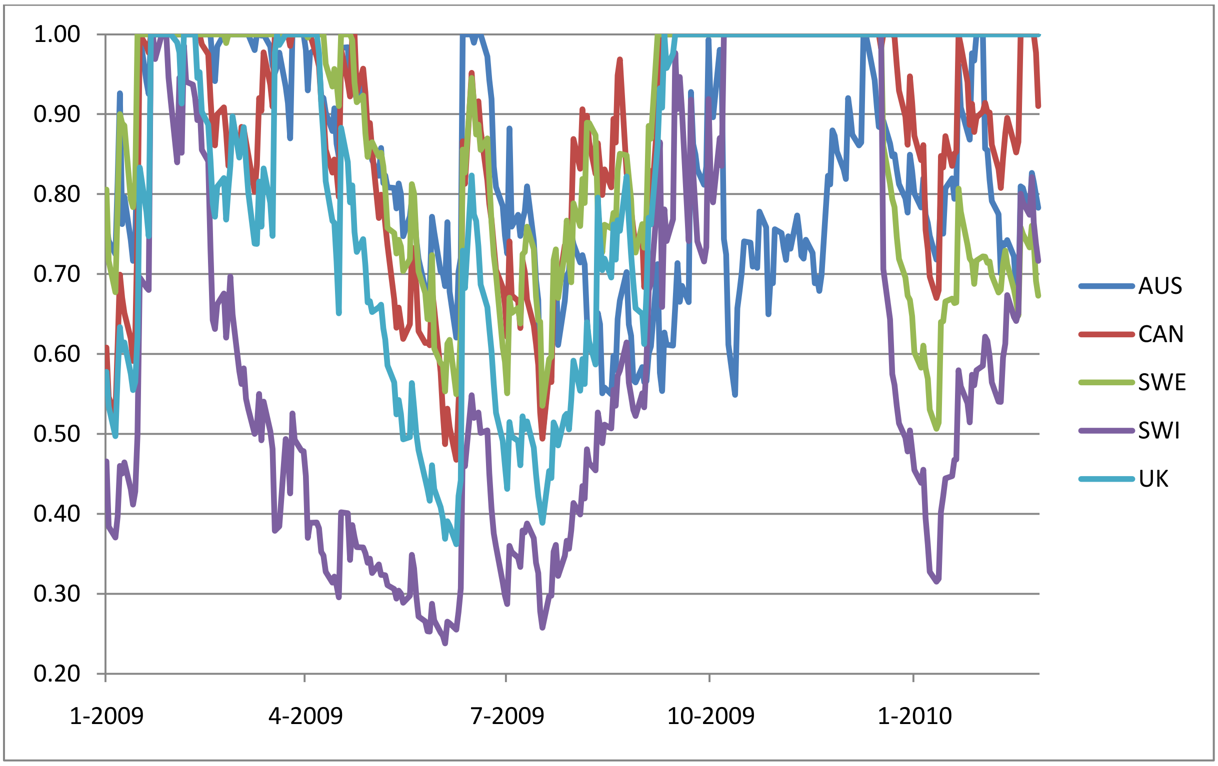
Developed Countries 01/01/2005 – 01/07/2008



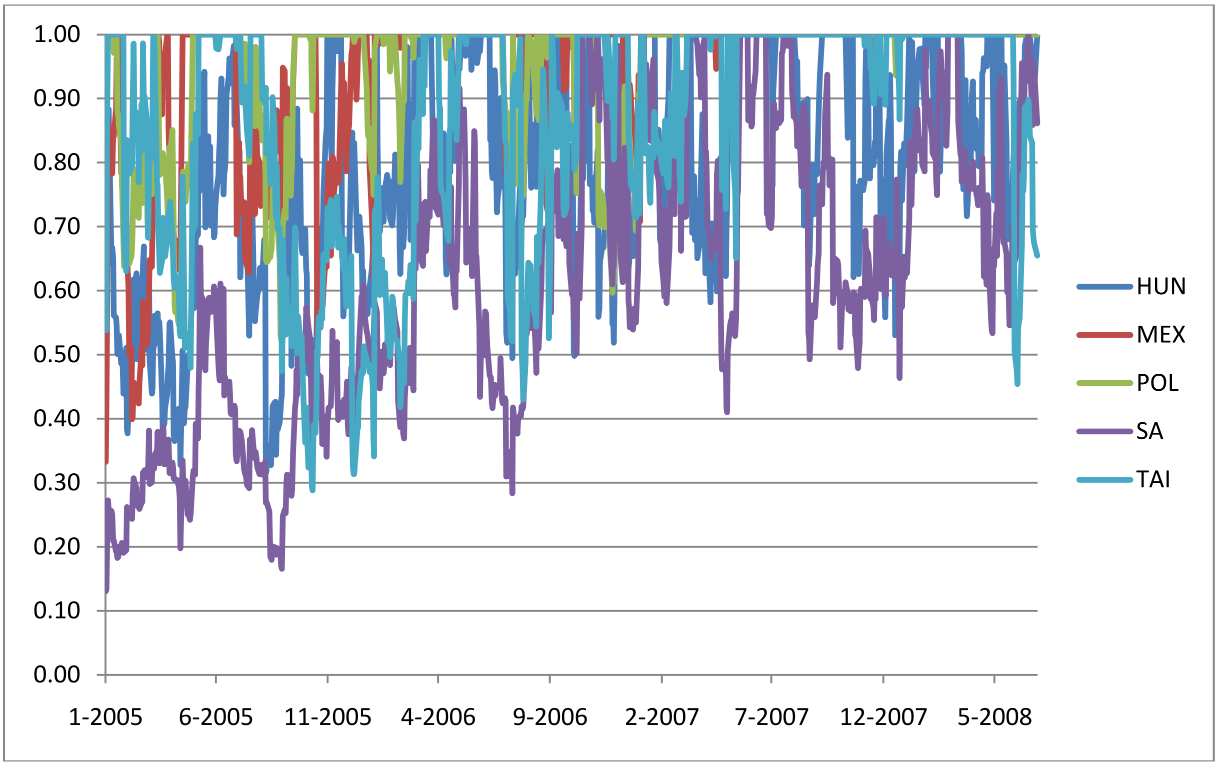
Developed Countries 01/07/2008 – 01/01-2009



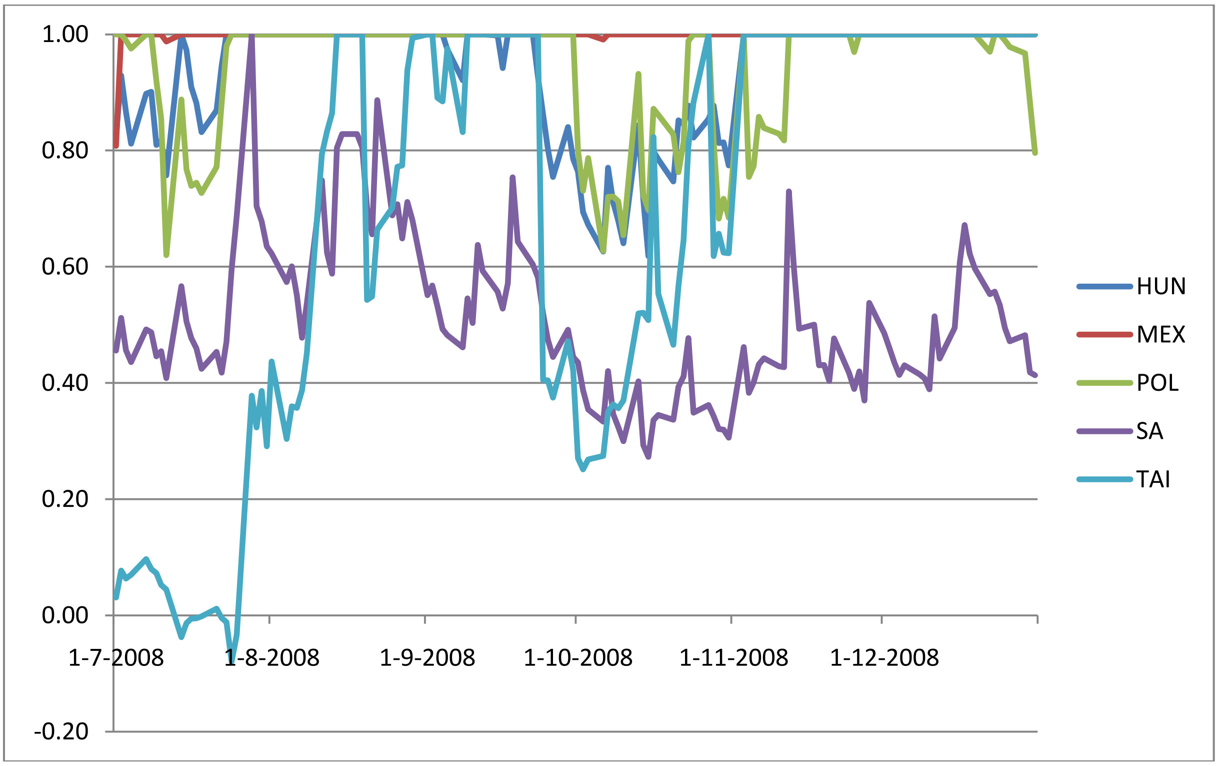
Developed Countries 01/01-2009 – 01/03/2010



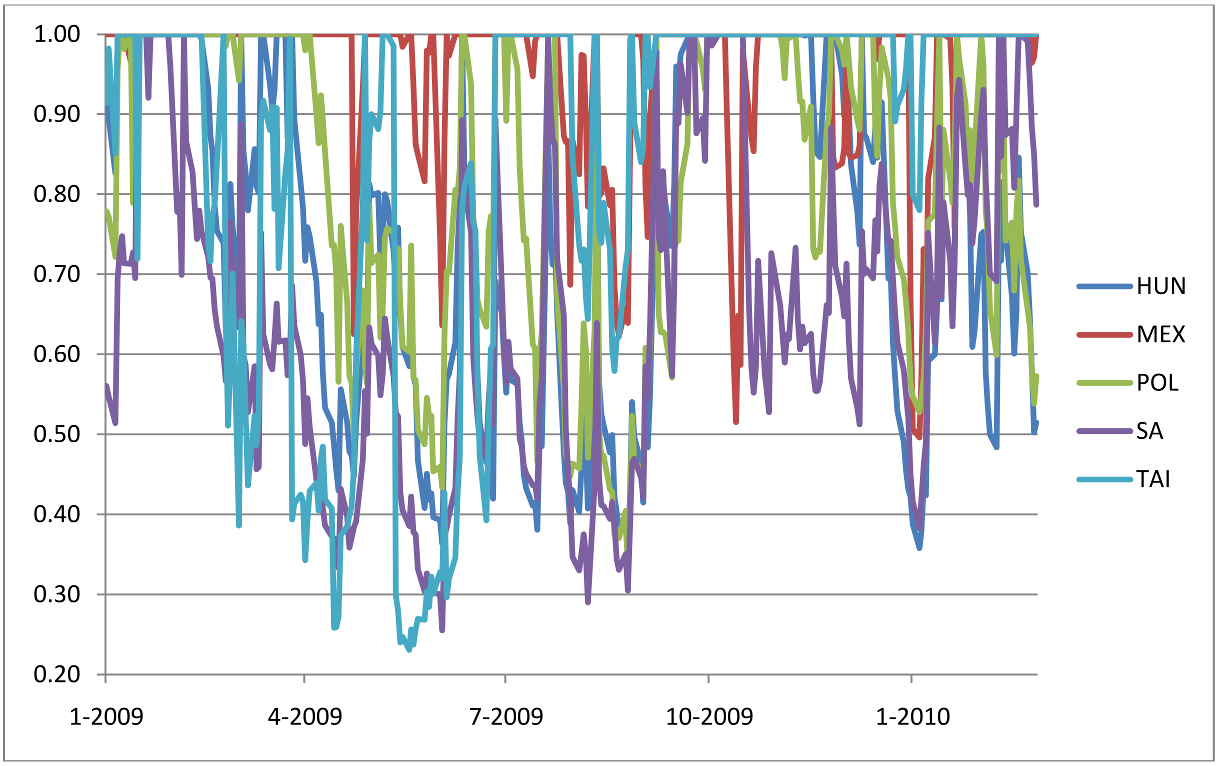
Emerging Countries 01/01/2005 – 01/07/2008



Emerging Countries 01/07/2008 – 01/01-2009

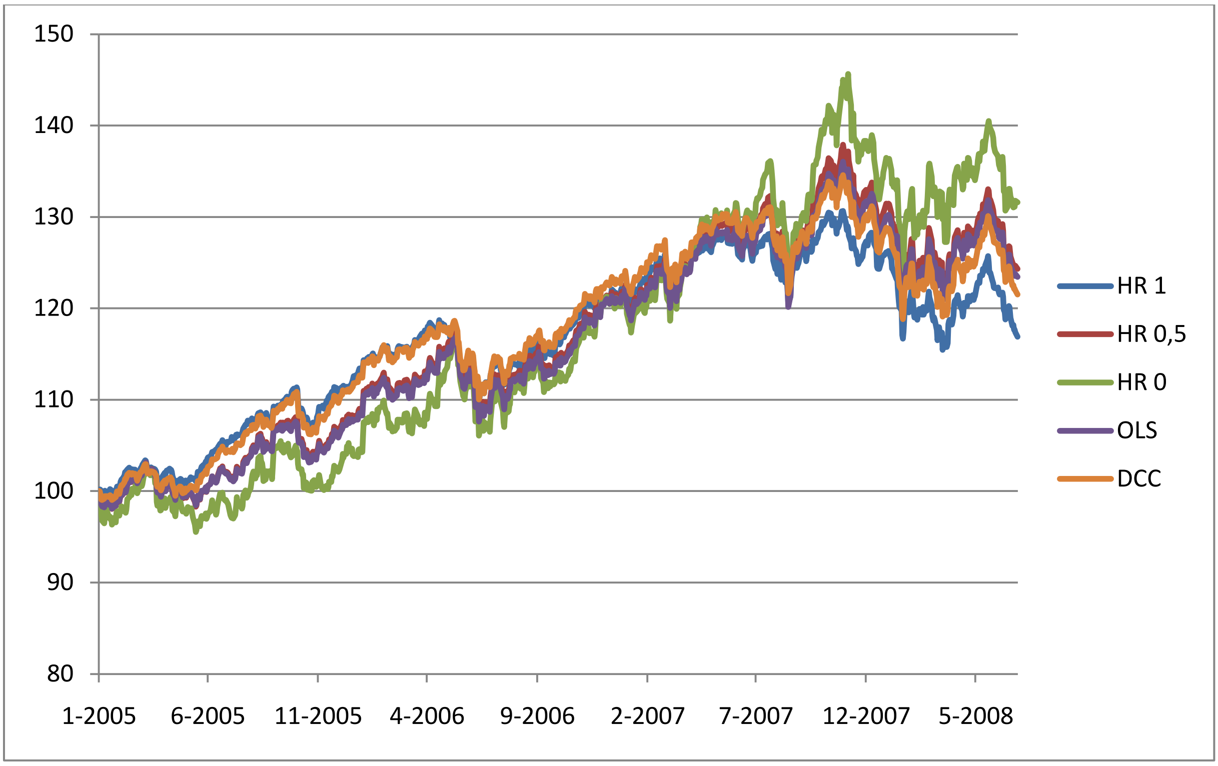


Emerging Countries 01/01-2009 – 01/03/2010

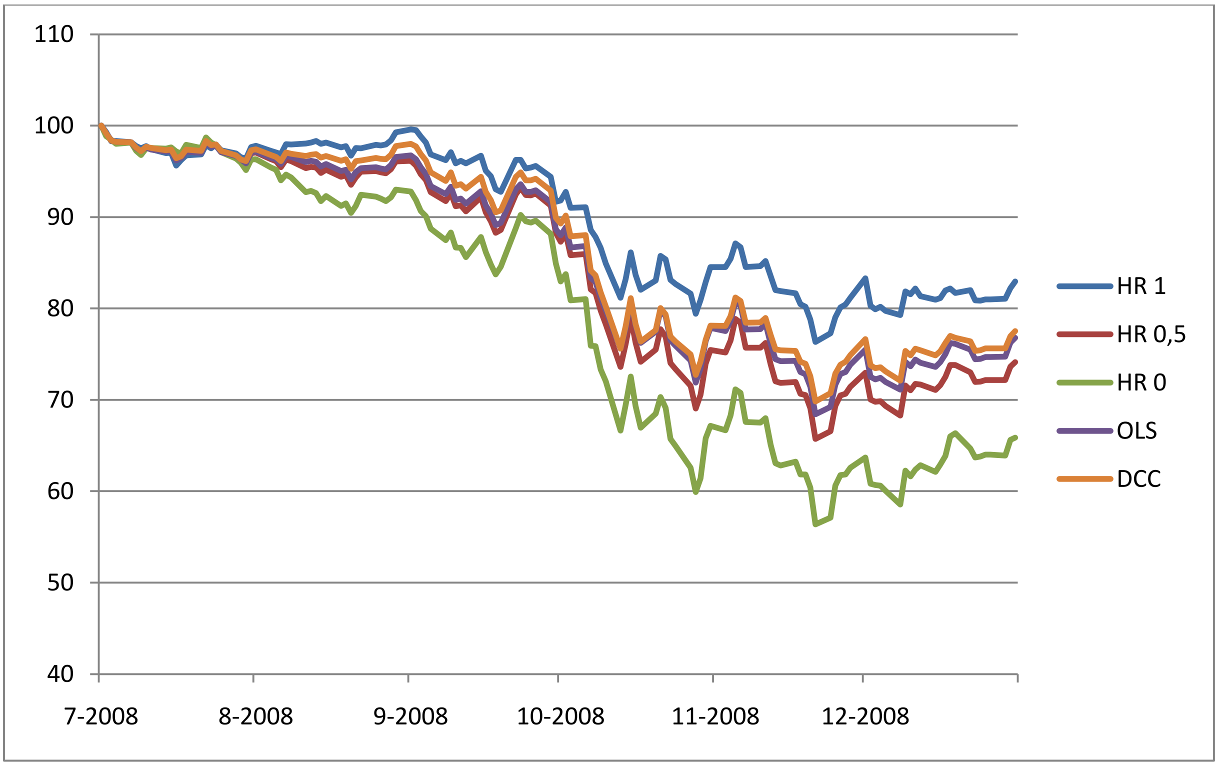


Appendix G: Performance Portfolios

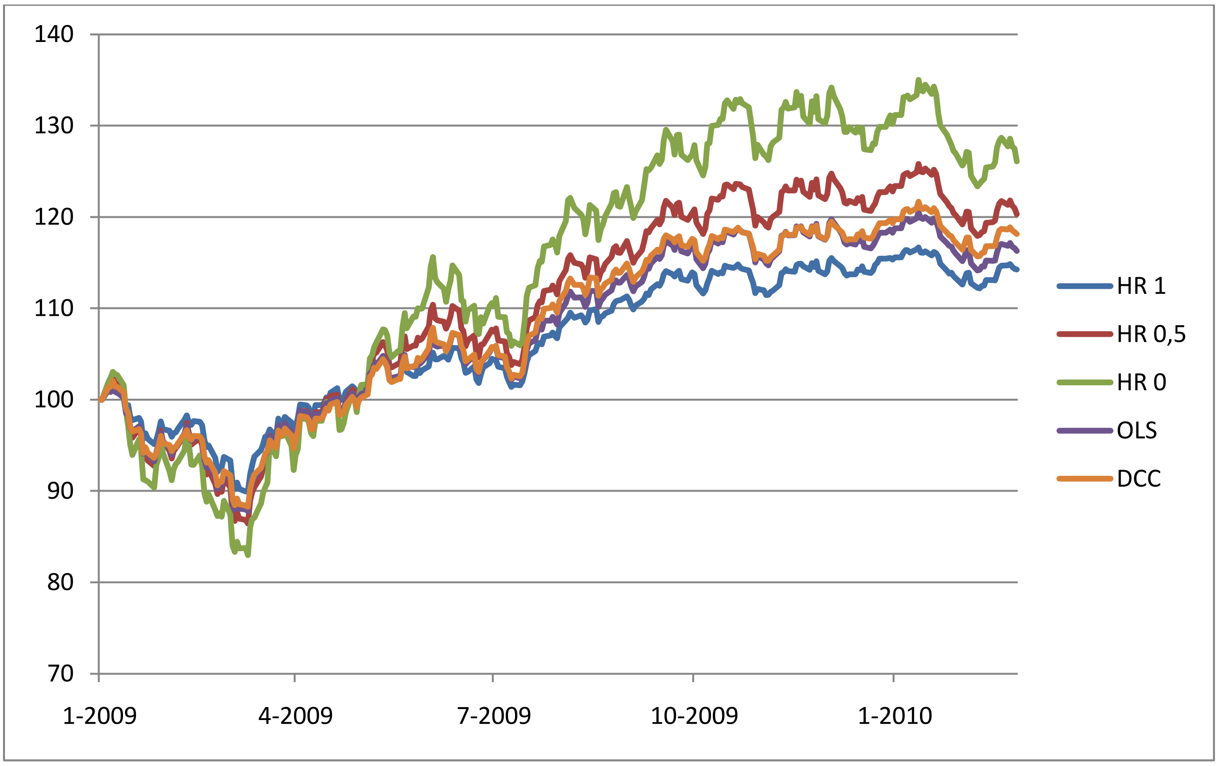
Developed Countries 01/01/2005 – 01/07/2008



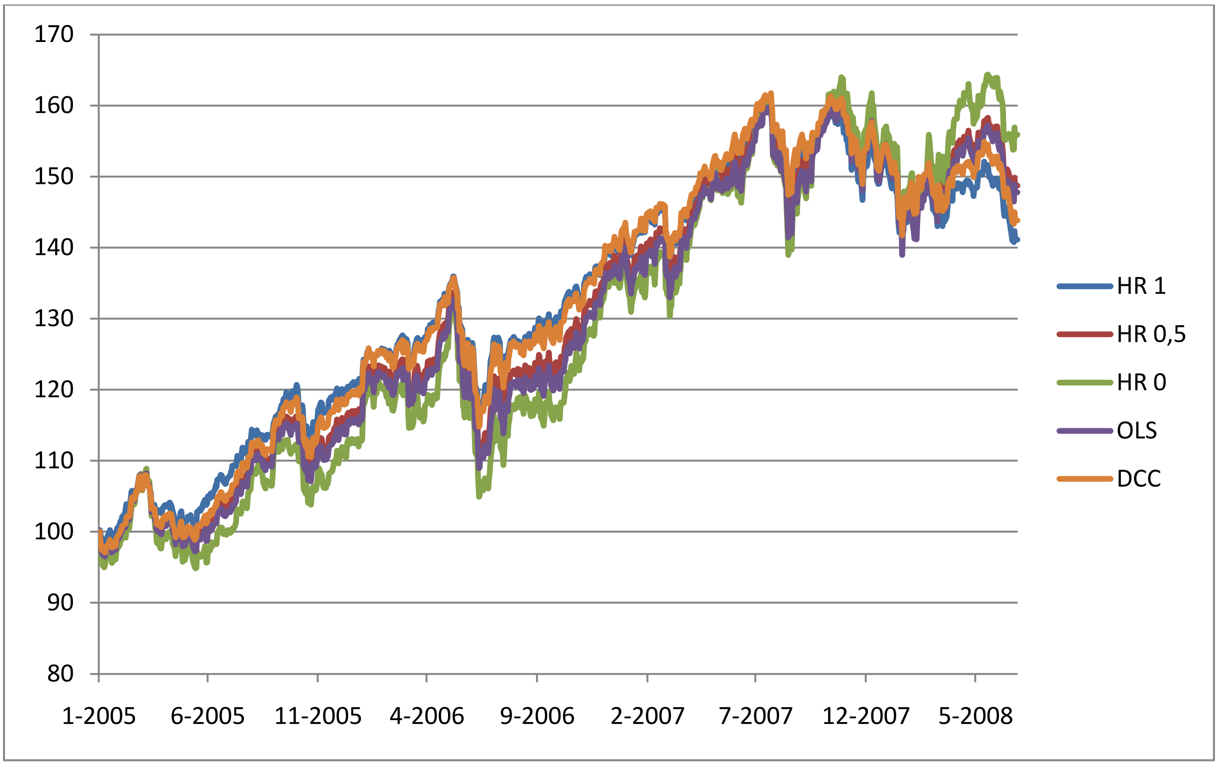
Developed Countries 01/07/2008 – 01/01-2009



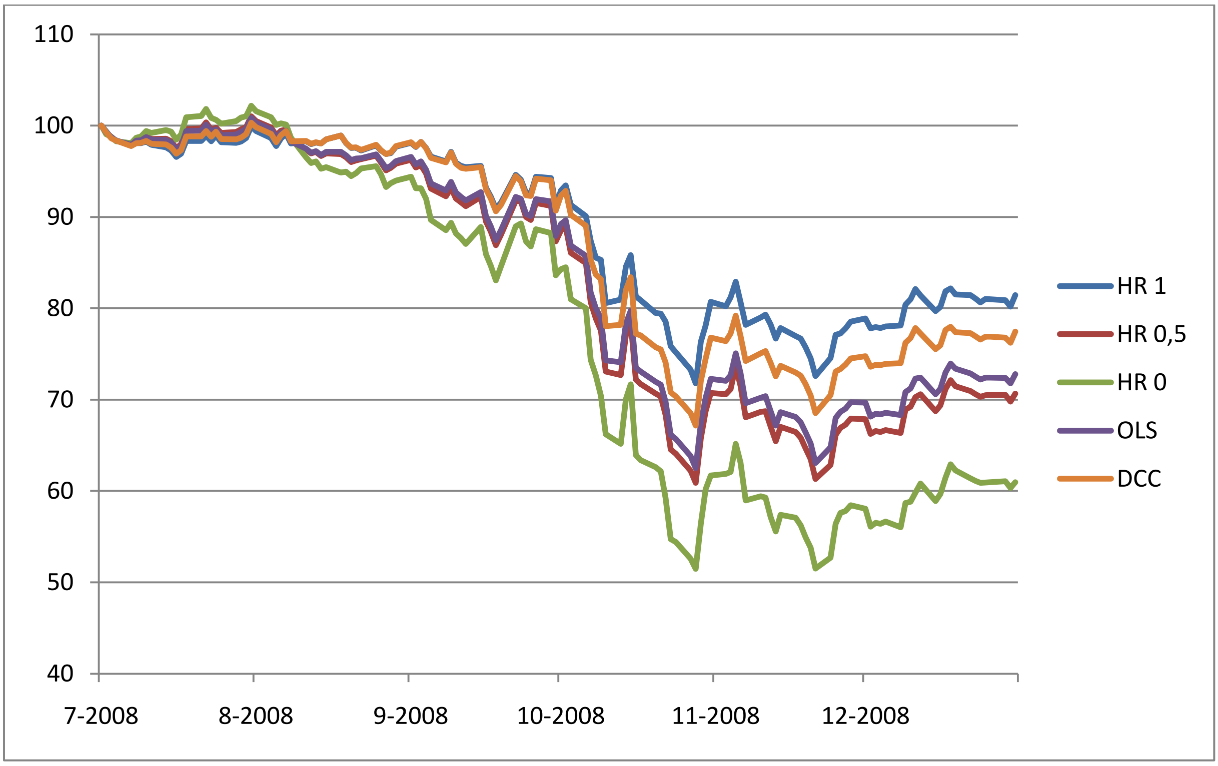
Developed Countries 01/01-2009 – 01/03/2010



Emerging Countries 01/01/2005 – 01/07/2008



Emerging Countries 01/07/2008 – 01/01-2009



Emerging Countries 01/01-2009 – 01/03/2010