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Currency Risk and the Government Pension Fund Global

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Abstract

The Government Pension Fund Global (GPFG) in Norway is a sovereign wealth fund with an international portfolio only invested in foreign securities. This paper aims to evaluate the currency exposure of the fund and assess how currency risk hedging impacts its performance. We find that the investments in assets denominated in foreign currencies expose the fund to an increased currency risk in terms of volatility. Although our out-of-sample strategies consistently manages to reduce portfolio risk, they do not provide any statistically significant changes in Sharpe ratio due to decreases in the average returns. We also observe that skewness typically worsens, and that kurtosis consistently increases. Only one strategy seems to provide a positive overall impact on portfolio performance. The hedge manages to reduce volatility and increase average return at the same time. Although it increases kurtosis, we only observe a marginal deterioration in skewness. Our results suggest that it may exist a strategy that could improve portfolio performance, but the results are not strongly statistically significant. Yet, the study does reveal a potential for currency risk hedging and points towards areas for improvement.

Keywords: sovereign wealth fund, currency risk exposure, currency hedge, portfolio management, risk management.

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ACRONYMS

CFH	Conditional Full Hedge
CMV	Conditional Minimum Variance
COH	Conditional Optimal Hedge
CUNIH	Conditional Universal Hedge
FH	Full Hedge
GPFG	Government Pension Fund Global
HR	Hedging Ratio
IPS	Investment Policy Statement
MV	Minimum Variance
NBIM	Norges Bank Investment Management
OLS	Ordinary Least Squares
SPRF	Sovereign Pension Reserve Fund
SWF	Sovereign Wealth Fund
UH	Unhedged Portfolio
UNIH	Universal Hedge

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I. INTRODUCTION

The Government Pension Fund Global (GPFG) in Norway was set up in 1990 to act as a buffer for the Norwegian economy and to share the petroleum revenues across generations. Norges Bank Investment Management (NBIM) manages the fund on behalf of the Norwegian people, and they invest in international equity, fixed-income markets and real estate. The fund's current allocation is 66.6% in equities, 31.8% in fixed income and 2.6% in unlisted real estate. These investments are exclusively in foreign securities. The asset allocation in terms of geographical areas consists of 36% in the European area, 41% in North America, 19.3% in Asia and Oceania, and 3.7% in the rest of the world according to their latest annual report (Norges Bank Investment Management 2018). This implies that the return on the GPFG measured in the domestic currency will vary with the changes in the exchange rate compared to the foreign currencies in which the fund is invested in, the size of the investment and their total weights.

Financial risk management is about using financial instruments to manage the exposure to risk. A large literature covers different hedging strategies for currency exposures. We will apply some of the most prominent strategies and measure the exposure before and after imposing the hedge. We start by analysing the background and characteristics of the GPFG, their investment policies and the long-term investment objectives. We will then investigate how their investment allocation affects their exposure to currency risk based on the collected data on the fund's investments and focus on the most dominant currency holdings. We will then measure the amount of risk the fund is exposed to in terms of currency fluctuations. The exposure is measured in terms of the returns' volatility, skewness and kurtosis. Further, the paper will focus on investigating the impact of currency hedging. Our main objective is to develop an analysis that can help sovereign wealth funds with similar characteristics as the GPFG to make decisions about future actions. The research questions we seek to answer is (I) to evaluate the fund's exposure to currency fluctuations, and (II) to assess how currency risk hedging will affect the performance of the fund. This is a topic we believe is important to address, especially because of the fluctuation in Norwegian krone (NOK) during recent years. Since 2014, NOK has depreciated relative to several of the largest currencies in which the fund is invested in. This has led to a large increase in the value of the GPFG measured in the domestic currency, in addition to an increase in the fund's contributions to the national budget. Such fluctuations in fund value caused by currency movements demonstrate the sensitivity of the portfolio in terms of currency exposure.

Section II of the paper describes the characteristics of sovereign wealth funds and global currency hedging, while section III reviews related literature on similar topics. Section IV provides relevant background theory for our study and describes their implications. It also elaborates on the methodology used and provides a detailed explanation of the statistical approach. Section V describes the data used in the paper with a description of how it was collected and treated. Section VI presents the empirical results while section VII concludes.

II. BACKGROUND

A Sovereign Wealth Fund (SWF) is a state-owned investment organization. They are pools of assets that are owned and managed directly or indirectly by governments to achieve national objectives. Such funds are set up to diversify and improve the return on foreign exchange reserves or countries' commodity revenues. They may also help shield the local economy from swings in commodity prices. This can be accomplished by investing in foreign assets (Blundell-Wignall 2008, p. 4). The International Monetary Fund and the Santiago Principles[3] have distinguished some of the main types of funds based on their stated policy objectives and asset allocation, where the GPFG is characterized as a savings fund. Such funds build up savings for future generations and they are characterized by a long-term investment horizon with limited liquidity needs. Blundell-Wignall (2008) characterizes the GPFG as a Sovereign Pension Reserve Fund (SPRF) where the fund is set up by the government to meet future deficits of the social security system. The investment policy statement (IPS) of GPFG[4]

[3] The Santiago Principles or Generally Accepted Principles and Practices (GAPP) are an initiative of the International Forum of Sovereign Wealth Funds (IFSWF) that reflects SWF's investment practices and objectives.
[4] Norges Bank Investment Management (2017b) covers the proposed strategy of the Government Pension Fund Global between 2017-2019.

provides guidelines for their investment strategy, stating that they should achieve the highest possible financial return subject to a moderate level of risk. Their strategic asset allocation in terms of their IPS is divided in 70% equity whereas the remaining allocation is invested in fixed income instruments and real estate (Norges Bank Investment Management 2018). Real estate may only account for up to 7% of the total assets. The assets are only invested abroad to avoid overheating the Norwegian economy, and to shield the economy from fluctuations in the oil price.

The current objective of the fund is to increase its international purchasing power. The performance of the fund is thereby expressed in both international currency terms and in NOK. However, it is important to address that parts of the fund's surplus are allocated back to the Norwegian economy due to the fiscal rule[5]. The introduction of assets denominated in foreign currencies will therefore impose an additional dimension of risk to these payouts. Any investment denominated in currencies different from the numeraire currency will pose a currency risk to the fund caused by fluctuations in the foreign currency rates. An important consideration when evaluating the risk exposure of the fund is therefore the currency in which returns are measured and the appropriate currency basket for the fund. Changes in the exchange rates can come from differences in the interest rates and inflation, or differences in the political stability and economic performance among countries or markets. This will, in turn, affect the total value of the fraction allocated to the annual government budget.

International diversification entails additional risk due to currency fluctuations. Figure I demonstrate the GPFG's historical positions in the largest currencies from January 1998 to December 2017. We can see that the fund's relative holding in each of the major currencies does not change significantly during the period. However, the proportion of the portfolio invested in euro has experienced a small decline while the relative holdings in USD have experienced a small increase during the full sample period.

[5] The fiscal rule states that the government intends to withdrawal up to 3 percent p.a. of the fund's value that is invested and expended in the Norwegian economy.

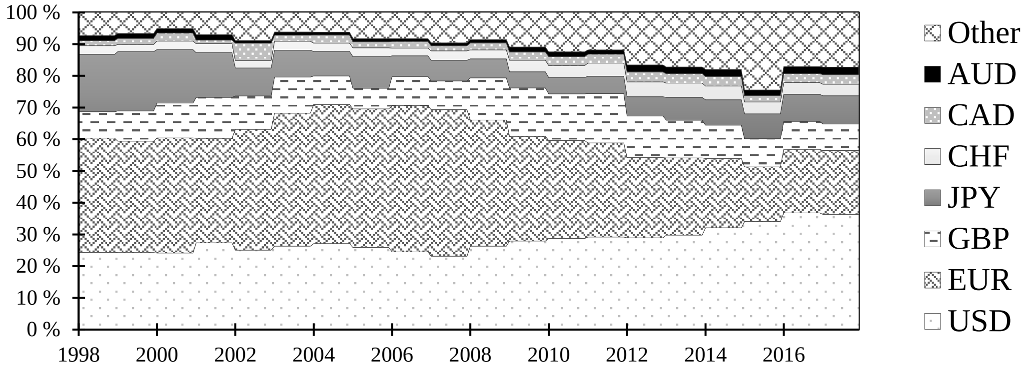

FIGURE I – Historical portfolio weights per annum in the currencies with the overall largest exposure to the portfolio in the period between 1998m1-2017m12.

To evaluate the currency exposure of the GFPG, we compare the continuously compounded return of the portfolio expressed in NOK and the return expressed in the currency basket. NBIM expresses the fund's return in the currency basket based on the return measured in NOK. They then geometrically adjust for the return of the currency basket which corresponds to the currency weights in the benchmark portfolio[6]. Figure II illustrates how the appreciation and depreciation of the NOK against the currencies in the benchmark portfolio affect the continuously compounded return of the fund. The two time series follow the same long-term trend and they are positively correlated. However, we can see that the continuously compounded return in NOK experiences larger local extremum compared to the return in the currency basket. This could indicate a higher volatility and a larger sensitivity to currency fluctuations when the return is measured in NOK instead of the return in the foreign assets alone.

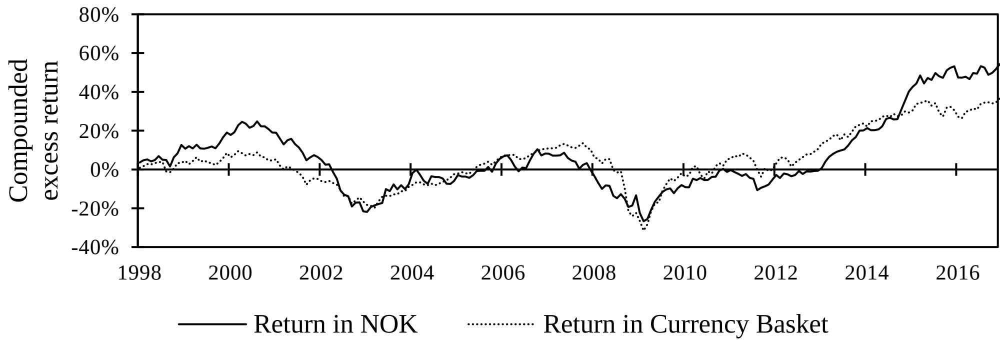

FIGURE II – Comparison of the continuously compounded return of the portfolio expressed in NOK and in the currency basket for the period between 1998m1-2017m12.

[6] The calculation methodology of returns applied by NBIM claims compliance with the Global Investment Performance Standards (Norges Bank Investment Management 2017a).

The level of sensitivity is reflected in Panel A of Figure III which compares the 24-months moving standard deviation of the return in NOK and the return in the currency basket. We see that the standard deviation of the NOK return is consistently higher, except for the period between 2008-2014. This is also highlighted in Panel B which shows the percentage difference of the variances.

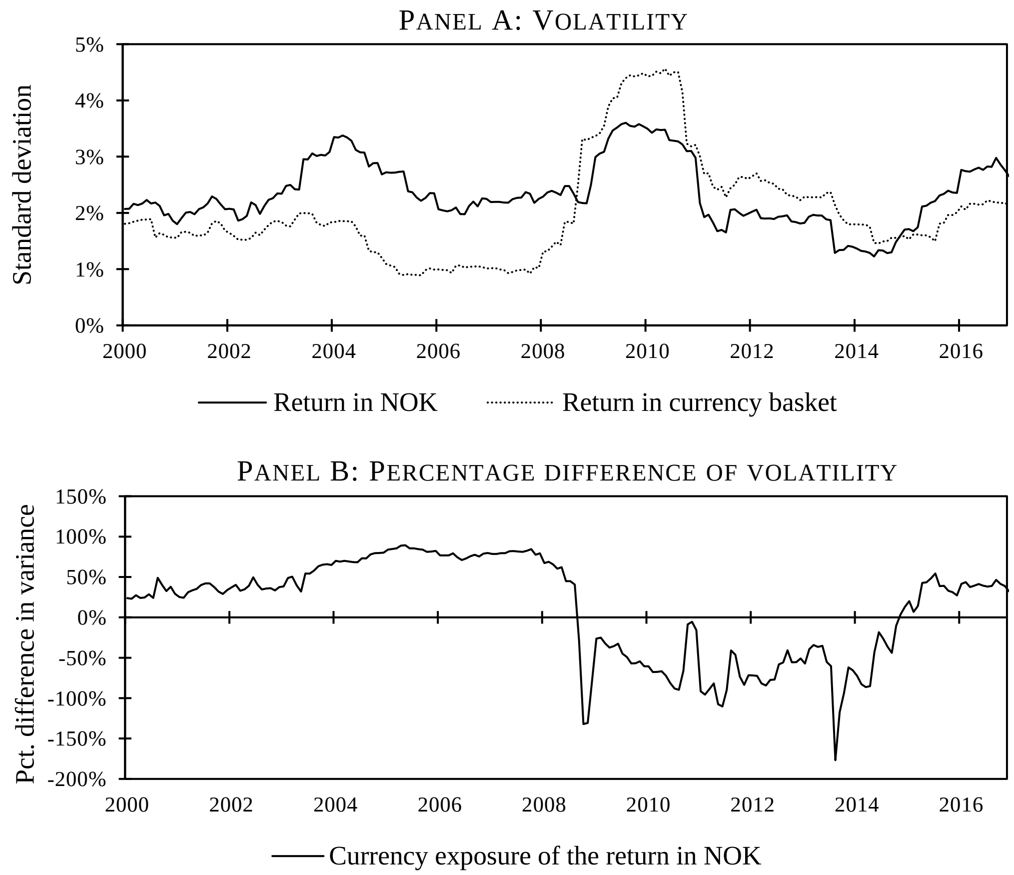

FIGURE III – Panel A compares the 24-months moving std.dev. of portfolio return expressed in NOK and in the currency basket. Panel B highlights the percentage difference of the variances by calculating the difference in variance between the NOK return and currency basket return, divided by the variance of the NOK return. We derive the expression of the percentage difference in the Appendix. Both graphs are for the period 2000m1-2017m12.

Foreign exchange hedging entails ways of minimizing such risk imposed by currency exposure. One way of increasing the risk-adjusted performance of the fund is to focus on diversification across financial instruments that are imperfectly correlated with the exchange rates. The fund can thereby invest in financial instruments that are imperfectly correlated with the currency rates. The main idea of such strategies is that any movement in the exchange rate will be offset by the imperfectly correlated instrument that moves in the opposite direction. The fund is thereby able to offset some of the risk exposure and prevent losses in certain situations. The most effective hedging instrument depends on the function of the risk exposure and will normally vary among different derivatives and investment vehicles.

III. LITERATURE REVIEW

A great amount of research describes the benefits and risks associated with having a portfolio exposed to foreign markets. One of the most compelling arguments for having investments in foreign markets is the benefits of diversification. Expanding the choice of markets should thereby provide an improved risk-return trade-off for your portfolio (Jorion & Khoury 1996). The benefits of such diversifications are driven by the correlation among the assets in a portfolio. Roll (1992) argues that the correlation across stock markets are low partly because countries tend to specialize in specific industries. The effects of such low correlations are demonstrated by Solnik (1974a) who shows that international equity portfolios outperformed the domestic U.S. portfolio in terms of volatility. However, foreign portfolio investments introduce an additional dimension of risk in terms of currency risk exposure. Such exposure can be hedged by using derivative instruments such as currency forwards. The controversial issue for every investor is whether currency risk should be hedged, and if yes, how much of the currency risk exposure that should be hedged. The optimal hedging ratio is subject to a large literature that we discuss in the remaining of this section. We then proceed with a review and a conclusion on where we stand today.

If currencies have zero expected return, they carry risk without reward. Perold and Schulman (1988) then advocate a unitary (full) hedge given that currency hedging provides a «free lunch». They state that hedging reduces the risk for both parties of a hedge. Either part will thereby gain on their hedge when their portfolio does badly. Considering minimal transaction costs, it is then possible to solely minimizing the portfolio variance while leaving the expected long-term returns unaffected. They do not necessarily suggest that the unitary hedge minimizes the risk, but that it removes most of it. Froot (1993), on the other hand, distinguishes between long and short time horizons. He argues that because real exchange rates revert to their means in the long-run, a full hedge does not provide risk reduction benefits for long horizons. Investors should therefore maintain an unhedged position. However, Froot acknowledges that real exchange rates may deviate from the theoretical fair value over shorter time horizons so that investors could benefit from currency hedging. Other research by Campbell et al. (2010) and Schmittmann (2010) looks at a larger number of currencies over a longer sample period and they do not find any horizon effects.

Instead of arguing between the two extreme hedging ratios, Black (1989) develops an optimal ratio for all investors that lies in between. His model relies on the assumptions that we have a frictionless market without any barriers to trade. He also assumes that every investor has the same level of risk aversion and that every investor is able to hedge against their currency risk exposure. Based on these assumptions, Black applied a general equilibrium framework to derive a universal hedging ratio that is optimal for all investors regardless of their nationality. The ratio will be the same for all investors and it reflects their average risk tolerance coefficient. The model has later been questioned by researchers given the practical limitations of the underlying assumptions. The criticism comes from the use of non-market weights when defining the quantities, and as discussed by Adler and Prasad (1992), the universality of the hedging ratios follows directly from the assumption of homogeneity on world investors. This is questionable because it requires all foreign investments to be in balance at all time, which rules out trade deficits (Jorion & Khoury 1996, pp. 295–298). However, Black still demonstrates the important result that it is never optimal to perform a unitary hedge of equity positions based on Siegel's paradox[7]. However, the universal hedging formula suggests a full hedge for foreign bonds. Foreign bonds that are held unhedged will be counted as part of the total exposure to foreign currency risk (Black 1995, p. 166). Hedging a smaller fraction of your holdings in foreign bonds should then be compensated by hedging a larger fraction of your holdings in stocks.

Other researchers have also investigated how different characteristics of asset classes affects the optimal hedging ratio. Solnik (1974a) demonstrates that a

[7] Siegel's paradox states that rational investors should be willing to embrace modest currency risk, at least if there is no exchange rate uncertainty due to differing interest rates or any imposition of the purchasing power parity (Siegel 1972). Under these assumptions, a full hedge is thereby never optimal.

unitary hedge is optimal when we have zero correlation between currency and equity returns for single currency exposures. However, De Roon et al. (2012) demonstrates that the optimal strategy is a minimum variance (MV) hedge whenever the correlation between exchange rate changes and equity returns are non-zero. Any positive correlation would thereby cause a depreciation in the foreign currency when the foreign investment experiences negative returns. Such currencies would therefore receive a negative weight in the portfolio. Campbell et al. (2010) applies the same framework and investigates how investors choose fixed currency weights to minimize the variance of their portfolio. They document that the U.S. dollar and the euro moved against the world equity markets over the period 1975 to 2005. They also found that currencies such as the Australian dollar, Canadian dollar, Japanese yen and British pound were negatively correlated with the world stock market. Based on their mean-variance optimization problem, investors should then want to take positions based on the correlation between currency returns and equity returns. Negative correlations suggest that investors should take long positions while positive correlations suggest taking short positions. Zero correlation suggests that the optimal strategy is a full hedge. They show that a MV hedge significantly improves the portfolio volatility compared to the unitary hedge. In terms of bond positions, they also find that currency returns are almost uncorrelated with bond returns. Investors should therefore fully hedge international bond positions. This is in line with the findings of Schmittmann (2010), documenting that the full hedge always outperforms other fractions for bond positions.

The previous theories rely on the assumption that currencies have zero expected return. By this assumption, currency risk hedging lets you reduce the variance of the portfolio while leaving the expected return unaffected. However, more recent studies performed by Dumas and Solnik (1995), De Santis and Gerard (1998) and Lustig and Verdelhan (2007) all suggest that currency risk offers a premium. The pricing of currency risk will effectively affect the expected return of a portfolio when hedging with currencies. It will also affect the volatility of the portfolio. Based on the argument of non-zero expected currency return, De Roon et al. (2012) suggests that currencies may not only be included in a portfolio to hedge against currency risk exposure but also for speculative reasons. Glen and Jorion (1993) also looks at the benefits of currency hedging for both stocks and bonds. They evaluate whether adding forward contracts to international portfolios significantly improves the risk-return profile of global investments. By using the results by Black (1989), they confirm that a unitary hedge ratio is suboptimal since such ratios ignore the correlations between exchange rates and local returns. It also ignores speculative motives for taking currency positions.

De Roon et al. (2012) investigate the effects of currency risk premiums and suggest that there is contradicting evidence towards the principle of a «free lunch» when hedging currency risk exposure. Instead of assuming that currencies have zero expected return, they find that hedging comes at a serious cost. In addition to the effect on volatility, they also focus on the effect on return and the first four order moments. The objective of their paper is to look at how hedging affects the overall performance of the portfolio. Their findings confirm that currency hedging does exactly what it aims to do by reducing the variance of the portfolio. However, it comes at the cost of lowering the average return of the portfolio. In fact, the out-of-sample Sharpe ratios do not significantly improve, and it often even deteriorates. In addition, currency risk hedging results in worsening in the portfolio skewness and increased kurtosis. The additional costs imposed by the hedge may therefore suggest that it could be more optimal to not hedge at all.

The topic of currency risk hedging underlies a great amount of literature that has traditionally looked at the effects of conditional and unconditional risk management. The findings of non-zero expected currency return suggest that currencies may be considered a separate hedging instrument (De Roon et al. 2012). Literature on the forward premium puzzle suggests that currencies with high short-term interest rates provide a high return on average[8]. Campbell et al. (2010) also find that increases in interest rates are associated with modest decreases in the covariance between currency and equity. Investors should thereby tilt their portfolio towards currencies with temporarily high interest rates. This is in line with the carry trade where you borrow in low-yielding currencies and invest in currencies with relatively higher yields. Incorporating forward premiums as a forecasting variable results in a conditional hedging strategy where the hedge ratio varies through time. Glen and Jorion (1993) find that conditional currency

[8] Supported by Hansen and Hodrick (1980), Fama (1984), Hodrick (1987) and Engel (1996).

hedging, where the hedge depends on prior interest rate differentials, outperforms unconditional strategies for both the unitary and universal hedge. However, it also comes at the additional costs discussed in the prior section considering the impact on the first higher order moments. De Roon et al. (2012) builds on the findings of Aggarwal (1990), who suggest that currency forward returns are typically not normally distributed, and the findings of Brunnermeier et al. (2009) who suggest that returns on currency carry trade are negatively skewed.

The literature has so far addressed the most common strategies for hedging currency risk. The unitary, universal and MV hedge relies on different assumptions which underlie numerous researches with focus on their effectiveness. All the theories support a full hedge for bond positions while the optimal ratio for equity positions differ. As argued by Jorion and Khoury (1996), both the unitary and universal hedge are special cases of a general optimization decision that involves assumptions that may not be reasonable. De Roon et al. (2012) demonstrates that hedging may come at a cost which could worsen the performance of the portfolio. They show that the traditional framework by looking solely at mean-variance performance is insufficient when assessing the performance of the hedge. Keeping the full exposure to currency risk without hedging could improve the relative portfolio performance when considering all the four lower order moments. Our study will investigate these results and evaluate how currency risk hedging affects the overall performance of the GPFG. We will also look at the effect of incorporating forward premiums as a forecasting variable to include a measure of how the timing affects the overall performance.

IV. THEORY AND METHODOLOGY

An international diversified portfolio will be subject to fluctuations in the exchange rates. Consider NOK as the numeraire currency while foreign assets are denominated in their respective foreign currencies. We thereby consider a Norwegian investor that holds assets denominated in foreign currencies. Currencies are quoted directly with the amount of NOK for each unit of foreign currency. We define $S_{i,t}$ as the NOK spot price for foreign currency *i* at time *t*, and $P_{i,t}$ as the asset price denominated in foreign currency *i* at time *t*. The return in NOK terms is thereby given as

$$R_{i,t+1}^{NOK} = \frac{P_{i,t+1}S_{i,t+1}}{P_{i,t}S_{i,t}} - 1. \tag{1}$$

Let us denote $x_{i,t}$ as the fraction of wealth that is invested in assets denominated in currency *i* at time *t*. The return on the portfolio can then be calculated as

$$R_{t+1}^{NOK} = \sum_{i=1}^{N} x_{i,t}\, R_{i,t+1}^{NOK}. \tag{2}$$

The position can be hedged by taking positions in forward contracts. Forward contracts involve a commitment to buy or sell a foreign currency at a future date depending on whether the investor takes a long or short position. Denote $(\omega_{i,t}\, x_{i,t})/S_{i,t}$ as the amount of currency *i* sold forward at time *t* for delivery at time *t+1*. The hedged return on the asset in currency *i* is then

$$R_{t+1}^{h} = R_{t+1}^{NOK} + \sum_{i=1}^{N}(-\omega_{i,t}\, x_{i,t})\ f_{i,t+1}, \tag{3}$$

where $f_{i,t+1} = (S_{i,t+1} - F_{i,t+1})/S_{i,t}$ is the payoff on a long position in a forward contract. Under covered interest parity, the one-month forward prices trades at $F_{i,t+1} = S_{i,t}(1 + i_{D,t})/(1 + i_{i,t})$ where $i_{D,t}$ denotes the domestic nominal one-month interest rate at time *t* and $i_{i,t}$ denotes the foreign nominal one-month interest rate at time *t.* We can thereby define any hedging strategy in terms of the hedging ratio $\omega_{i,t}$. The key question is what hedging ratio that is optimal.

According to our discussion on empirical literature, the issue of choosing the optimal hedging ratio is based on different theoretical and practical assumptions. Some choose to fully hedge while others choose not to hedge or to lie somewhere in between. The optimal hedging ratio is a result of competing forces and it is difficult to implement a strategy that can simultaneously satisfy all investors given their unique concerns and constraints. Following De Roon et al. (2012), we apply the minimum variance hedge and uses the unitary and universal hedges as robustness checks. This allows us to assess the impact of the different assumptions on our results. We also enter speculative positions following literature on carry trade, as well as separating our analysis in two sub-sample periods. We will use the results to evaluate the performance of the hedged position for a portfolio with the characteristics of the GPFG. Considering the theoretical background and previous empirical studies, the working hypothesis is thereby that the hedged position outperforms the unhedged position of the fund during our period of interest.

A. *Currency Hedging of the Portfolio*

Our base portfolio is the Norwegian GPFG. The fund is invested in over 77 countries around the world and some investments in specific countries are relatively small compared to others. For simplicity, our study will only focus on the currencies which imposes the largest overall exposure to the fund. We will include members of the Group of Seven (G7)[9], Switzerland and Australia. G7 currently includes Canada, France, Germany, Italy, Japan, the U.K. and the U.S. Switzerland and Australia is included because of the fund's significant investment in assets denominated in Swiss franc and Australian Dollar. The exclusion of certain currency positions implies that some currencies will not be hedged directly. We are also leaving real estate unaffected from our hedge given that it has only made up about 2% of the total fund value during our sample period. Our focus in terms of asset classes is thereby equities and bonds given that it makes up most of the values in the fund. Rebalancing is performed monthly and we disregard any transaction or taxation costs. The calculation of the hedging position for every month will be based on the preceding 60 months of data. The full hedging period is therefore January 2003 to December 2017.

Our approach will be subject to some simplistic assumptions. We will impose the hedge for both the unconditional and conditional versions of the unitary, universal and MV hedge in an overlay fashion by managing the currency risk separately. The overlay strategy is argued to be second-best to the global portfolio optimization problem after active currency management. The reason is that it ignores the interaction between the core portfolio and currencies. However, the setup is common practice by many institutional investors where they often delegate their core portfolio selection to specialized managers while the currency risk is managed separately (Jorion & Khoury 1996, pp. 300–301). We also know that bond positions should be treated different than equity positions because of the low correlation between bond and currency returns. However, we will make a simplistic approach when constructing our hedged portfolio by not managing the asset classes separately.

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[9] The Group of Seven (G7) is a group of the largest advanced economies in the world currently consisting of Canada, France, Germany, Italy, Japan, the U.K. and the U.S.

The hedging ratios for each strategy will depend on the relevant theories discussed in the previous literature. To evaluate the unitary hedge, we will apply a full hedging ratio of $\omega_{i,t} = -1$. It implies hedging one unit of foreign currency for every unit the fund is invested in that foreign currency. The hedging ratio for the universal strategy proposed by Black (1989) is determined by the world market portfolio. The ratio is determined by the aggregate risk aversion coefficient,

$$\omega_t = \frac{\mu_m - \sigma_m^2}{\mu_m - \frac{1}{2}\sigma_e^2}, \tag{4}$$

where μ_m is the average excess return on the market portfolio, σ_m^2 is the average variance of the holdings on the market portfolio and σ_e^2 is the average variance of the exchange rates across all pairs of countries (Black 1995, pp. 162–163). The average values are viewed and weighted by the investment amount from each country. The input values are based on the preceding 60 months of data.

The MV hedge entails using a mean-variance analysis to find the foreign currency position that minimizes the risk of the overall portfolio. We will calculate such a hedging position by applying an ordinary least squares (OLS) regression. To evaluate the currencies, we run a regression of the portfolio return in the numeraire currency on the forward return in the numeraire currency. The numeraire currency is defined as NOK. To evaluate the exposure of the portfolio, we calculate the slope coefficient in the OLS regression of the unhedged portfolio returns on a constant and the currency returns. The model is expressed as

$$\begin{aligned} R_\tau^{NOK} &= \beta_0 + \beta_1 f_{1,\tau}^{NOK} + \beta_2 f_{2,\tau}^{NOK} + \ldots + \beta_N f_{N,\tau}^{NOK} + \varepsilon_\tau \\ &= \beta_0 + \sum_{i=1}^{N} \beta_i f_{i,\tau}^{NOK} + \varepsilon_\tau \end{aligned} \tag{5}$$

for $\tau = t-1, \ldots, t-60$. We denote R_τ^{NOK} as the excess return on the unhedged international portfolio in the numeraire currency, while $f_{i,\tau}^{NOK}$ denotes the currency forward return of NOK against currency *i*. This leads to the out-of-sample hedged country position $R_{i,t}^h$ with a hedging position $\omega_i x_{i,t} = \beta_{i,t}$, where

$$\beta_i = \frac{Cov(R_\tau^{NOK}, f_{i,\tau}^{NOK})}{Var(f_{i,\tau}^{NOK})}. \tag{6}$$

A positive covariance between the currency and portfolio return indicates that we would experience a depreciation in the foreign currency when the foreign investment has a negative return. Currencies with negative covariance with the portfolio return will therefore have a negative weight in the hedging portfolio, indicating that we should have a short position in the forward contract. The hedged return is then found by

$$R_{t+1}^{h} = R_{t+1}^{NOK} - \sum_{i=1}^{N} \beta_{i,t} \times f_{i,t+1}. \quad (7)$$

B. Conditional Hedging Strategies

The conditional hedging strategy will exploit the framework of currency carry trade where you take long positions in currencies with high interest rates and short positions in currencies with low interest rates. We will use this framework to evaluate whether the use of forward premiums as a forecasting variable will provide additional value for the hedge. We will use the same framework as Campbell et al. (2010, pp. 110–114) by assuming that currency demand depends linearly on interest differentials. The interest differentials are measured monthly and are expressed as $i_{f,t} - i_{l,t}$ where $i_{f,t}$ denotes the foreign riskless interest rate at time *t* while $i_{l,t}$ denotes the local riskless interest rate at time *t*. An interest differential of $i_{f,t} - i_{l,t} > 0$ would therefore suggest an appreciation of the foreign currency relative to the numeraire currency. However, a differential of $i_{f,t} - i_{l,t} < 0$ would suggest an expected depreciation of the foreign currency rate relative to the numeraire currency. We are imposing the hedge whenever $i_{f,t} - i_{l,t} \leq 0$, while we leave the portfolio unhedged whenever $i_{f,t} - i_{l,t} > 0$.

The hedging ratio (HR) when $i_{f,t} - i_{l,t} > 0$ for the unitary hedge is $HR = -\omega_i$, while the hedging ratio for the universal strategy is given by equation (4). The strategy for the minimum variance hedge follows from the same OLS approach as in equation (5) for the preceding 60 months in each period. Let us denote Σ_{CP} as the covariance matrix of all the currencies with the portfolio returns. We also denote Σ_{CC} as the covariance matrix of all the currencies with itself. The units of foreign currency that should be hedged for every unit the fund is invested in that foreign currency is thereby given by

$$HR_{MV} = -\frac{\Sigma_{CP}}{\Sigma_{CC}}. \quad (8)$$

We are thereby removing the currencies that should not be hedged *ex-post* of running our regression. However, this approach could be suboptimal given that it also includes currencies that should not necessarily be hedged when optimizing the hedging ratios for those currencies that should be hedged. We are therefore also testing a modified approach which we call the conditional optimal hedge (COH) where we only include those currencies where $i_{f,t} - i_{l,t} > 0$ when modelling our regression. We introduce the use of the dummy variable $D_i = 1$ for our hedging ratio whenever $i_{f,t} - i_{l,t} > 0$, and $D_i = 0$ for the hedging ratio whenever $i_{f,t} - i_{l,t} \leq 0$. The OLS model is then given by

$$r_\tau^{NOK} = \beta_0 + \beta_1 f_{1,\tau}^{NOK} D_1 + \beta_2 f_{2,\tau}^{NOK} D_2 + \ldots + \beta_N f_{N,\tau}^{NOK} D_N + \varepsilon_\tau$$

$$= \beta_0 + \sum_{i=1}^{N} \beta_i \, f_{i,\tau}^{NOK} D_i + \varepsilon_\tau, \qquad (9)$$

$$\text{for } \tau = t-1, \ldots, t-60.$$

This approach allows us to improve the accuracy of the hedging ratios by removing the currencies that should not be hedged *ex-ante* of running our regression. We are then denoting Σ_{CP^*} as the covariance matrix of only the currencies that should be hedged with the portfolio return. We also denote Σ_{CC^*} as the covariance matrix of only the currencies that should be hedged, with itself. The hedging ratio for the conditional optimal hedge (COH) is then given as

$$HR_{COH} = -\frac{\Sigma_{CP^*}}{\Sigma_{CC^*}} \qquad (10)$$

C. *Performance Evaluation*

We use the same approach as De Roon et al. (2012) in order to evaluate how the currency hedge affects the first four moments of the portfolio returns. The approach follows the method of moments methodology where we start by evaluating the trade-off between return and volatility, and the impact on skewness and kurtosis. We consider the Sharpe ratio that was introduced by William F. Sharpe (1966 & 1975) to measure the performance of the hedged and unhedged position in terms of reward-to-variability. As for De Roon et al (2012, pp. 10–12), we allow for non-normality to compare and test for differences in the Sharpe ratio between different sets of assets. The test is based on the method of moments and it does not rely on normality assumptions. The Sharpe ratio (SR) is expressed as

$$SR = \frac{E[r_t]}{\left(E[r_t^2] - E[r_t]^2\right)^{1/2}} = \frac{m_1}{\left(m_2 - m_1^2\right)^{1/2}}, \qquad (11)$$

where r_t is the excess return on the portfolio consisting of equity and bond positions, and m_z is the order of moment z. A relatively high ratio implies that we have a relatively high reward in terms of excess return compared to volatility. The moments are estimated using

$$\frac{1}{T}\sum_{t=1}^{T}(r_t^z - m_z) = \frac{1}{T}\sum_{t=1}^{T} u_{z,t} = 0. \qquad (12)$$

We use the same approach as laid out in Appendix A from De Roon et al. (2012, p. 31) to test for changes in Sharpe ratios. Let us similarly denote $\Omega(\widehat{SR})$ as the limiting variance of the Sharpe ratio difference. Let us also assume that the true difference between the Sharpe ratios of portfolio A and B equals θ. As shown by De Roon et al., the limiting distribution is then given by

$$\sqrt{T}\left(\left(\widehat{SR}_A - \widehat{SR}_B\right) - \theta\right) \rightarrow N\left(0, \Omega\left(\widehat{SR}\right)_{AB}\right). \qquad (13)$$

For the skewness, we will focus on standardized skewness measured as the third central moment divided by the cube of the standard deviation. This procedure is common in the literature and the advantage of this standardization is that the resulting measure of skewness is invariant to changes in scales (De Roon et al. 2012, pp. 11–12). Such scaling is needed to make the skewness measures for different portfolios comparable. The skewness (SK) of the returns r_t in terms of moments is expressed as

$$SK = \frac{E[(r_t-\mu)^3]}{\sigma^3} = \frac{m_3 - 3m_2m_1 + 2m_1^3}{\left(m_2 - m_1^2\right)^{3/2}}. \qquad (14)$$

The skewness provides a measure of the asymmetry of the distribution and thereby also its downside or upside risk. However, the measure of kurtosis will extend our analysis by providing a measurement of the probability of the risk. A lower kurtosis will, in turn, have a lower probability of returns around the mean. The kurtosis (K) of the returns r_t in terms of moments is expressed as

$$K = \frac{E[(r_t-\mu)^4]}{\sigma^4} = \frac{m_4 - 4m_3m_1 + 6m_2m_1^2 - 3m_1^4}{\left(m_2 - m_1^2\right)^2}. \qquad (15)$$

As for De Roon et al. (2012), we apply the same methodology when testing for differences in means, standard deviation, skewness and kurtosis. It follows in an analogous way as the test for differences in Sharpe ratios as discussed in Appendix A from De Roon et al. (2012, pp. 31–33).

V. DATA AND SUMMARY STATISTICS

Data on the allocations of the GPFG are retrieved from the databases of NBIM. We have obtained the monthly return of the fund denominated in NOK return from December 1997 to December 2017. From the same database, we have also obtained data on the yearly holdings in terms of country and currency given that shorter frequencies are not publicly available. However, from the yearly holdings in Figure I, we see that the currency exposures do not change significantly from one year to another. We are therefore imposing the assumption that the currency weights are relatively constant during each fiscal year. Real estate was first introduced as an asset class in the fund in 2010. The fund currently has an upper bound on what should be invested in real estate based on the fund's total market value which is 7%. However, in 2017 the real estate investment accounted for only 2.7% of the total assets under management. Given that we only have data on real estate investments from 2010 and that its value is relatively negligible compared to the overall market value of the fund, it is not included in our calculations of the funds' monthly return.

Data on monthly foreign exchange rates and interest rates are retrieved from Datastream[10]. The interest rates we use are the 1-month LIBOR[11] interest rate for the G7 countries including Switzerland, the 1-month NIBOR[12] interest rate for Norway and the 1-month deposit rate for Australia. Given that Canada discontinued the use of LIBOR in July 2013, we use the CAD 1-month deposit rate from July 2013 and until the end of 2017. Since the European Union was first established in 1999, the recorded data on the euro LIBOR started in 1999. We are therefore using the German 1-month deposit rate as a proxy in the period December 1997 to December 1998. Both the 1-month interest rate data and the foreign exchange rate data for each month contains the end of the month quote.

Table I provides the summary statistics per annum for the monthly interest rate and monthly returns for the full hedging period. We see that NOK had the

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[10] Datastream is a financial time series database offered by Thomson Reuters.

[11] London Interbank Offered Rate (LIBOR) is the benchmark rate that leading banks charge each other for short-term unsecured loans.

[12] Norwegian Interbank Offered Rate (NIBOR) is the rate that Norwegian banks charge each other for short-term unsecured loans denominated in Norwegian krone.

second largest average interest rate per annum among all currencies during the period from 2003 to 2017. The only currency with a higher average interest rate is AUD which is 1.7 percentage points above NOK. Since the Australian interest on average is higher than the Norwegian interest, this can lead to many unhedged positions in the AUD when employing the conditional approach. In contrast to the high Australian interest rate, we find a relatively low interest rate in Japan. This can lead to a more frequent employment of hedging positions against the JPY because of the lower average interest rate in Japan compared to Norway. However, if interest rate differentials are an unbiased predictor of currency movements, it could imply that the GPFG would benefit from currency appreciations by keeping the portfolio hedged in the lower interest countries.

Over the full hedging period, we see that the GPFG have a positive average return on all the seven currencies. This implies that the fund on average has increased their portfolio returns by not employing any currency hedges. This is also the case for AUD despite having the highest interest rate. The summary statistics for our sub-samples are provided in Exhibit A and B.

TABLE I – SUMMARY STATISTICS FOR THE FULL HEDGING PERIOD

PANEL A	NOK	USD	EUR	GBP	JPY	CHF	CAD	AUD
1-month interest rate p.a.								
Average	2.4998%	1.4924%	1.3316%	2.2389%	0.1800%	0.3604%	1.8570%	4.2194%
Std.dev.	1.5030%	1.7532%	1.5346%	2.1615%	0.2393%	0.9664%	1.3433%	1.5984%

PANEL B	NOK/ USD	NOK/ EUR	NOK/ GBP	NOK/ JPY	NOK/ CHF	NOK/ CAD	NOK/ AUD
Monthly currency return p.a.							
Average	1.8246%	2.3029%	0.4270%	2.4955%	3.9950%	3.0859%	3.8350%
Std.dev.	11.8475%	7.2795%	9.8364%	14.3540%	9.7059%	9.3050%	9.4762%
Monthly return on Forwards long position p.a.							
Average	0.7864%	1.1232%	0.1465%	0.1543%	1.8090%	2.4194%	5.5517%
Std.dev.	11.7954%	7.2385%	9.8211%	14.2916%	9.6623%	9.2720%	9.4305%

NOTE: Summary statistics for the full hedging period between 2003m1–2017m12. Panel A reports the per annum average 1-month interest rate and the standard deviation for each currency. Panel B reports the per annum monthly average excess return and monthly return on forwards and their corresponding standard deviation for each pair of currency.

Table II provides the correlation matrix of currency excess returns among each pair of NOK against the other currencies. All pairs of currencies have a positive correlation during the hedging period. The lowest correlation is between the pair of CAD with the pair of EUR (41.45%) while the highest correlation is between the pair of JPY with the pair of USD (74.56%). The high correlations could be explained by financial links and integrated economies. Japan and the United States are two major economic powers with such interconnected economies. The same applies to the Swiss franc with its high interconnection with the European market. The imperfect correlations suggest that we could obtain some diversification benefits from having foreign currency positions in our portfolio.

TABLE II – CORRELATION MATRIX OF CURRENCY RETURNS

	NOK/ USD	NOK/ EUR	NOK/ GBP	NOK/ JPY	NOK/ CHF	NOK/ CAD	NOK/ AUD
NOK/USD	1						
NOK/EUR	0.5101	1					
NOK/GBP	0.6570	0.5417	1				
NOK/JPY	0.7447	0.4748	0.4449	1			
NOK/CHF	0.5242	0.6728	0.4339	0.5977	1		
NOK/CAD	0.5791	0.4104	0.5291	0.4278	0.4278	1	
NOK/AUD	0.2577	0.4636	0.3814	0.2285	0.3476	0.5481	1

NOTE: Correlation matrix of pair of the numeraire currency against foreign currencies for the full period of interest between 2003m1–2017m12. The correlation coefficients are based on currency returns.

VI. EMPIRICAL RESULTS

The hedging period is defined from January 2003 to December 2017 and our out-of-sample forecasts are based on the preceding 60 months. We start by looking at the impact of our defined hedging strategies in terms of the portfolios mean and variance. We include the unhedged portfolio performance to evaluate the statistical significance of the impacts. The results are evaluated for both the full hedging period and for our two defined sub-periods. All results reflect the overall performance of the hedges from the perspective of the GPFG.

A. FULL SAMPLE HEDGING RESULTS

The results for the full hedging period are reported in Table III for all hedging strategies. We see that all the hedging strategies manage to reduce the overall risk of the portfolio. For instance, the standard deviation reduces from 8.57% in the unhedged portfolio to 7.07% in the conditional optimal hedge (COH). This is a reduction of -17.46%. The other strategies vary between a reduction of -6.57% and -22.82%, where the MV hedge has the largest decrease in volatility. The risk reduction is statistically significant at the 5% level for all strategies, except for the full hedge, conditional full hedge and the conditional MV hedge.

TABLE III – HEDGING PERFORMANCES FOR THE FULL HEDGING PERIOD

	UH	FH	CFH	UNIH	CUNIH	MV	CMV	COH
Mean	6.05%	5.62%	5.18%	5.43%	5.13%	5.04%	5.37%	6.74%
t-stat	2.6622	2.8141	2.4471	2.8192	2.5244	2.8869	2.6838	3.5817
t-stat$_{(hedged\text{-}unh)}$		-0.1389	-0.2746	-0.2020	-0.2935	-0.3437	-0.2190	0.2267
Std.dev.	8.57%	7.54%	8.01%	7.29%	7.70%	6.61%	7.57%	7.07%
t-stat	16.2201	10.5260	11.9329	13.2245	12.7974	12.2218	15.3527	12.9196
t-stat$_{(hedged\text{-}unh)}$		-1.4255	-0.8421	-2.9180	-1.9735	-2.9022	-1.8212	-2.2641
Sharpe ratio	0.71	0.75	0.65	0.75	0.67	0.76	0.71	0.96
t-stat	2.5294	2.4420	2.2153	2.5086	2.3145	2.6629	2.5570	3.2873
t-stat$_{(hedged\text{-}unh)}$		0.1626	-0.2667	0.2628	-0.2689	0.2204	0.0294	0.9657

NOTE: Per annum average excess return, standard deviation and Sharpe ratio for the unhedged and hedged positions during the full sample period. The results are shown for the unhedged portfolio (UH) and the defined strategies: full hedge (FH), conditional full hedge (CFH), universal hedge (UNIH), conditional universal hedge (CUNIH), minimum variance (MV), conditional minimum variance (CMV), and the conditional optimal hedge (COH). The *t*-statistics for both mean, std.dev. and Sharpe ratio are for the null hypothesis that it is significantly different from zero. The *t*-statistics for the differences (hedged-unh) reports whether the values remain unchanged after adding currency hedging positions.

By assuming that currencies have zero expected return, optimal currency hedging would solely minimize the portfolio variance. If we also assume that the correlation between the base assets and currency returns are zero, Perold and Schulman (1988) argue that the unitary hedge would be able to reduce most of the variance while leaving long-run returns unaffected. However, Campbell et al. 2010) shows that correlation is typically non-zero for equity-base portfolios. Our results also show that the risk reduction comes at the cost of lowering the average portfolio return for almost all strategies. This is consistent with De Roon et al. (2012) who argue that currencies have a risk premium and thereby a non-zero expected return. The decreases in returns vary between -7.13% and -16.68%. The conditional optimal hedge is the only strategy that experiences both a decrease in volatility and an increase of 11.38% in the mean. However, even though the means are statistically significant at the 5% level alone, the changes are not.

To evaluate how the risk reduction affects the overall performance in terms of portfolio return, we look at the risk-return trade-off reflected by the Sharpe ratio. The trade-offs are almost the same, but we do experience some improvements. The unconditional strategies seem to improve the Sharpe ratios for both the unitary and universal strategies, while the conditional strategies decrease the Sharpe ratios. These changes vary between -8.43% and 7.96% for all strategies, except for the conditional optimal hedge who increases the Sharpe ratio by 34.94%. Even though each of the Sharpe ratios are statistically significant at the 5% level alone, the changes are not even statistically significant at the 20% level.

Our results indicate that most of the strategies lower risk without any significant changes in neither average return nor Sharpe ratio. The conditional optimal hedge is the only strategy which both improves the overall portfolio volatility and return. Although it also performs best in terms of increasing the Sharpe ratio the most, the change is not statistically significant.

B. Sub-Sample Hedging Results

The first sub-sample starts from January 2003 to June 2010. The beginning of the period is characterized by an economic recovery from the stock market crash around the turn of the century. Influential events for Norwegian investors during this period include the great oil price increase that eventually burst at the end of 2008. This is partly explained by the financial crisis that hit the global economy in 2008 and led to a global recession. The results from the first sub-sample are presented in Panel A of Table IV. We observe similar results as for the full sample period, although the test statistics are somewhat lower. This could partly be explained by the smaller sample size. The observations show that all the hedging strategies manage to reduce portfolio risk. The MV hedge provides the largest decrease in standard deviation of -24.85% compared to the unhedged position. This is also the only strategy that yields a statistically significant change at the 5% level. We do observe some improvements in the means for certain strategies. The full hedge, universal hedge and the conditional optimal hedge are the only positions that provide an increase in average returns. Despite the reduction in volatility, the Sharpe ratios increase for the respective strategies as a result of the higher average returns. However, common for all strategies is that none of the average returns or Sharpe ratios alone are statistically significant at even the 20% level. The same result also applies to each of the changes in both average return and Sharpe ratio.

TABLE IV – HEDGING PERFORMANCES FOR THE SUB-SAMPLES

PANEL A: FIRST SUB-SAMPLE

	UH	FH	CFH	UNIH	CUNIH	MV	CMV	COH
Mean	2.17%	2.36%	1.55%	2.20%	1.66%	0.10%	-0.10%	2.28%
t-stat	0.6247	0.7335	0.4515	0.6902	0.4921	0.0397	-0.0342	0.8022
t-stat$_{(hedged-unh)}$		0.0415	-0.1244	0.0068	-0.1040	-0.4755	-0.4886	0.0249
Std.dev.	9.40%	8.74%	9.36%	8.42%	9.16%	7.07%	8.41%	7.70%
t-stat	11.7134	7.6690	8.9469	9.5811	10.8214	8.7733	11.9654	9.8482
t-stat$_{(hedged-unh)}$		-0.5739	-0.0438	-1.0685	-0.3687	-2.2371	-1.1625	-1.6850
Sharpe ratio	0.23	0.27	0.17	0.26	0.18	0.01	-0.01	0.30
t-stat	0.6194	0.6994	0.4420	0.6698	0.4843	0.0397	-0.0342	0.7803
t-stat$_{(hedged-unh)}$		0.1352	-0.2632	0.1338	-0.3308	-0.5865	-0.9072	0.1861

PANEL B: SECOND SUB-SAMPLE

	UH	FH	CFH	UNIH	CUNIH	MV	CMV	COH
Mean	10.07%	8.97%	8.92%	8.76%	8.72%	10.21%	11.12%	11.38%
t-stat	3.4988	3.9094	3.7471	4.1792	3.9804	4.5764	4.6044	4.7961
t-stat$_{(hedged-unh)}$		-0.2873	-0.2962	-0.3529	-0.3597	0.0349	0.2668	0.3344
Std.dev.	7.54%	6.04%	6.27%	5.52%	5.77%	5.84%	6.30%	6.18%
t-stat	11.6836	11.3397	12.0079	9.6617	10.2727	9.4803	9.9442	9.0396
t-stat$_{(hedged-unh)}$		-2.5171	-2.2497	-4.9484	-4.6874	-2.3676	-2.1780	-1.8471
Sharpe ratio	1.34	1.49	1.43	1.60	1.52	1.76	1.78	1.85
t-stat	3.0783	3.2641	3.2133	3.3071	3.2594	4.1885	4.0469	4.4455
t-stat$_{(hedged-unh)}$		0.3922	0.2560	1.0098	0.8084	1.2024	1.8101	1.6732

NOTE: Per annum average excess return, standard deviation and Sharpe ratio. Panel A reports the results for the first sub-sample period from January 2003 to June 2010. Panel B reports the results for the second sub-sample period from July 2010 to December 2017. The results are shown for the unhedged portfolio (UH) and the defined strategies: full hedge (FH), conditional full hedge (CFH), universal hedge (UNIH), conditional universal hedge (CUNIH), minimum variance (MV), conditional minimum variance (CMV), and the conditional optimal hedge (COH). The *t*-statistics for both the mean, std.dev. and Sharpe ratio are for the null hypothesis that it is significantly different from zero. The *t*-statistics for the differences (hedged-unh) reports whether the values remain unchanged after adding currency hedging positions.

The second sub-sample extends from July 2010 to December 2017. This period is characterized by an expansion in the world market resulting from a recovery after the financial crisis in 2008. Another influential event with potential impact on Norwegian investors is the second decline in oil prices in 2014. The steep drop in oil prices was effectively one of the main drivers of the depreciation of NOK in the subsequent period, as seen in Exhibit D. The drop in oil prices was caused by numerous factors like the stagnation of the rapid growth of large economies like China, Russia, India and Brazil after 2010, as well as an increase in oil production by the U.S and Canada. The results for the second sub-sample is reported in Panel B of Table IV. Unlike the full sample and first sub-sample, the test statistics are now slightly higher. The strategies still manage to reduce portfolio risk in the range of -16.46% and -26.75%. All changes are also statistically significant at the 5% level, except for the conditional optimal hedge which is statistically significant at the 10% level. Although most of the strategies reduce the average return of the portfolio, we still see that the MV hedge, conditional MV hedge and the conditional optimal hedge increases the average returns. Each of the average returns are statistically significant at the 5% level alone, but the changes are not. In terms of the risk-return trade-off, we do observe improvements for all strategies which could be explained by the large decrease in volatilities. Although the tests for Sharpe ratios suggest that the hedging strategies improves the risk-return trade-off, we do not detect any significant changes at the 5% level. However, the conditional optimal hedge is superior in terms of risk-adjusted returns with a statistically significant change at the 10% level.

C. Unconditional versus Conditional Hedge

The use of interest rate differentials follows the well-known carry trade strategy. This is a speculative strategy where we take non-zero expected currency returns into account when constructing our hedge. Figure IV provides a visual representation of the unconditional and conditional strategies of the minimum variance hedge. The corresponding performance of the unitary and universal strategy is presented in Exhibit C.

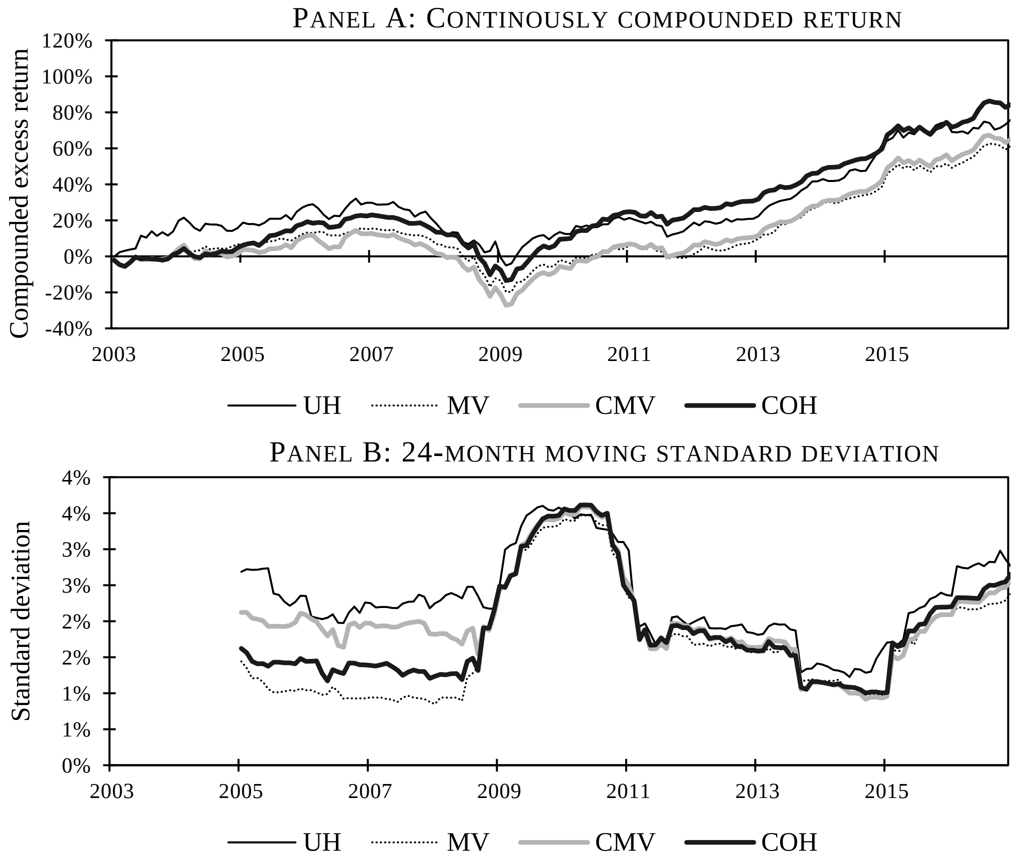

FIGURE IV – Panel A reports the continuously compounded excess return for the unhedged portfolio (UH) and the minimum variance (MV), conditional minimum variance (CMV), and conditional optimal hedge (COH) between 2003m1–2017m12. Panel B reports the volatility measured in standard deviation based on the 24-month moving standard deviation. The first reported standard deviation is therefore in 2005m1.

The figure clearly reflects what is reported in Table III–IV. We see that the MV hedge performs slightly better than the conditional MV hedge during the first sub-sample period, and slightly worse during the second sub-sample period. However, the differences are very small, and they follow the same movement throughout the full hedging period. Both strategies manage to reduce the volatility relative to the unhedged portfolio, but they also come at the cost of lowering the average return of the portfolio. We would expect that the use of carry trade strategies would provide a higher risk-return trade-off. However, we see in Table III that the average Sharpe ratio for the unconditional hedge is higher than for the conditional strategy. These results contradict our initial expectation that the conditional approach can preserve those currency returns that plain hedging strategies cut off. By looking at Table III–IV and Exhibit C, we observe similar results for the unitary and universal hedges.

One of the weaknesses of the conditional MV hedge is that the hedging ratios for those currencies that should be hedged are affected by the correlation with those currencies that should not be hedged. The conditional optimal hedge avoids the problem by only including the currencies that should be hedged in the regression model. Figure IV and Table III demonstrates that the modified strategy outperforms the conditional MV hedge in terms of reducing the portfolio risk. Although the risk is higher compared to the unconditional strategy, it significantly increases the average return compared to both the MV and the conditional MV hedge. For that reason, we also observe a superior risk-return trade-off reflected by the Sharpe ratio. By controlling for the correlation between currencies in the hedging ratios for the COH, we can construct a conditional model that seems to be capable of exploiting the non-zero expected currency returns.

The carry trade strategy is conditional on the interest rate differential. The conditional hedge will only outperform the unconditional hedge if interest rate differentials on average are able to predict the currency movements in the next period. Hence, the performance of the conditional strategies depends on the prediction accuracy of the interest rate differential. To evaluate the predicting power, we measure the frequency of correct and incorrect predictions in our out-of-sample forecast. The results are reported in Table V.

TABLE V – PREDICTION ACCURACY

	USD	EUR	GBP	JPY	CHF	CAD	AUD	Avg.
Full period	49.44%	47.22%	48.33%	55.56%	51.11%	47.78%	53.89%	50.48%
Sub-sample 1	51.11%	46.67%	50.00%	56.67%	55.56%	45.56%	52.22%	51.11%
Sub-sample 2	47.78%	47.78%	46.67%	54.44%	46.67%	50.00%	55.56%	49.84%

NOTE: Prediction accuracy reflected as the percentage of periods the interest rate differential manages to correctly predict the direction of the currency pairs between two currencies during the full sample period (2003m1–2017m12), the first sub-sample period (2003m1–2010m6) and the second sub-sample period (2010m7–2017m12).

The accuracy varies between 47.22% for the euro pair and 55.56% for the Swiss franc pair for the full sample period. On average, the accuracy of the forecasting is 50.48% across all currency pairs during this period. We consider this to be low given that it is close to flipping a coin. Interest rate differentials alone seems to be a weak predicting tool for the movement in the foreign currencies relative to the numeraire currency. This could explain some of the poor performances for most of the conditional strategies, except for the conditional optimal hedge which performs superior despite the low accuracy. Because of the weak predicting power in interest rate differentials, it could be subject for further improvements. By looking at other forecasting methods, we believe that minor improvements in the accuracy could improve the performance of the conditional strategies.

D. Impact on Higher Order Moments

The impact of currency risk hedging on the third and fourth moments of portfolio returns are reported in Table VI. Panel A reports the impact on skewness while Panel B reports the impact on kurtosis. We are not only interested in evaluating the impact on each performance measures individually, but also combined.

TABLE VI – SKEWNESS AND KURTOSIS

PANEL A	UH	FH	CFH	UNIH	CUNIH	MV	CMV	COH
Skewness	-0.406	-1.219	-0.974	-0.992	-0.818	-0.554	-0.354	-0.412
t-stat	-1.584	-2.449	-2.243	-2.885	-2.709	-1.314	-1.388	-1.063
t-stat$_{(hedged-unh)}$		-1.446	-1.137	-1.719	-1.346	-0.297	0.151	-0.012

PANEL B	UH	FH	CFH	UNIH	CUNIH	MV	CMV	COH
Kurtosis	3.721	7.462	6.028	5.859	4.950	5.793	4.038	5.290
t-stat	1.011	2.139	1.763	2.490	2.038	3.809	2.172	3.078
t-stat$_{(hedged-unh)}$		1.621	1.194	1.639	1.108	2.089	0.377	1.542

NOTE: Comparison of skewness (Panel A) and kurtosis (Panel B) during the full hedging period between 2003m1–2017m12. The results are shown for the unhedged portfolio (UH) and the defined strategies: full hedge (FH), conditional full hedge (CFH), universal hedge (UNIH), conditional universal hedge (CUNIH), minimum variance (MV), conditional minimum variance (CMV), and the conditional optimal hedge (COH). The *t*-statistics for skewness are for the null hypothesis that it is significantly different from zero, while the corresponding value for kurtosis is for the null hypothesis that the excess kurtosis is significantly different from zero. The *t*-statistics for the differences (hedged-unh) reports whether the values remain unchanged after adding currency hedging positions.

We find that the unhedged average returns are negatively skewed. However, the skewness is not statistically significant at the 5% level. Adding a hedge deteriorates the skewness for all the strategies except for the conditional MV hedge. The decrease is especially large for the unitary hedge which experiences a decrease of almost 200%. Such deterioration in skewness could imply that the portfolio increases the frequency of small positive returns and the frequency of few larger negative returns. In general, the conditional strategies seem to provide smaller deteriorations than the conditional strategies. It also looks like the hedges based on the minimum variance strategy outperforms the universal and unitary hedge. The conditional MV hedge even improves the skewness from -0.406 to -0.354 which is an improvement of 12.82%. However, the changes in skewness are only statistically significant at the 20% level for unitary and universal hedges.

Our next step is to investigate the impact of currency risk hedging on the portfolio kurtosis for the full hedging period. We see that the unhedged average returns have a positive excess kurtosis. However, the excess kurtosis is not statistically significant at the 5% level. Adding a currency hedge always increases the kurtosis of the portfolio and they are all statistically significant at the 5% level. This is consistent with the results by De Roon et al. (2012). The economic magnitude of the increases is also large. For instance, kurtosis increases from 3.721 in the unhedged portfolio to 5.290 in the conditional optimal hedge. This is an increase of 42.14%. The other hedges vary between an increase of 8.50% and 100.52% where the full hedge has the largest overall impact. A higher kurtosis itself is not necessarily considered bad for investors. Combined with an improvement in skewness, it could indicate a higher probability of experiencing a lower downside risk. This is the case for the conditional MV hedge which experiences both a reduction in skewness and an increase in kurtosis. However, for all other hedges, we experience a higher kurtosis combined with a more negative skewness. This is a negative combination which could indicate that the probability of larger downside risk increases. However, although the excess kurtosis for every strategy except the conditional unitary hedge is statistically significant at the 5% level, the changes are only statistically significant for the MV hedge at the given significance level.

VII. CONCLUSION

The Government Pension Fund Global (GPFG) in Norway is a sovereign wealth fund with an international portfolio of investments only in foreign securities. The introduction of assets denominated in foreign currencies imposes an additional dimension of risk to the fund in terms of currency risk. A large literature covers different hedging strategies for managing currency exposures. The benefit of currency hedging has traditionally only been assessed by its impact on portfolio volatility. However, De Roon et al. (2012) shows that the presence of currency risk premiums makes hedging come at the cost of also affecting the average return, skewness and kurtosis of the portfolio. This paper aims to evaluate the currency exposure of the GPFG and assess how currency risk hedging impacts the performance of the fund in terms of its first four moments.

We construct out-of-sample strategies where the hedging ratios are based on the preceding 60 months of data. Following De Roon et al. (2012), we apply the minimum variance hedge and use the unitary and universal hedges as robustness checks. We also enter speculative positions following literature on carry trade as well as separating our analysis in two sub-sample periods. From our analysis, we find that currency risk hedging manages to reduce the overall risk of the portfolio. The average portfolio returns also decrease, but the impact on the risk-adjusted return is not evident from our results. Although the Sharpe ratios improve for certain strategies, none of the changes are statistically significant. By looking at the higher order moments, we find that the skewness mostly worsens and that the excess kurtosis increases for all strategies. This is a negative combination that could result in a higher probability of downside risk. However, the results are not statistically significant and therefore not fit for a conclusion.

Only one strategy seems to provide a positive overall impact on portfolio performance. According to our results, the conditional optimal hedge is in fact able to reduce the portfolio volatility significantly and at the same time increase the average mean for both the full hedging period and the two sub-samples. Although it increases kurtosis, we only observe a marginal deterioration in skewness from -0.406 to -0.412. The strategy seems to do the job of reducing portfolio risk without any large negative impacts on the other order moments. However, we would still recommend further research to strengthen our conclusion. Given the lack of strong statistical significance in our results, we are unable to provide a consistent conclusion as to whether currency risk hedging provides any positive impact on portfolio performance.

Our study is subject to several considerations that may affect our result. The small sample size, financial crises and oil price fluctuations could impact our test statistics and the predicting power of the interest rate differentials. Despite the large literature on carry trade strategies, we observe that those hedges that are conditional on interest rate differentials perform relatively worse on average. The overall result could partly be explained by the poor forecasting accuracy of interest rate differentials which is close to flipping a coin. Another consideration is the absence of managing the different asset classes separately. Given the low correlation between currency returns and fixed income returns, they should be treated differently in an optimal hedging strategy.

Overall, our study provides important insight into how currency exposures affect sovereign wealth funds with similar characteristics of the GPFG. We also show how different currency hedging strategies not only affect risk, but also average return, skewness and kurtosis. Based on the large currency exposure, we do believe that currency hedging could provide additional value to the fund. It would be interesting for further research to investigate whether the results are consistent when replicated without our discussed problems. We believe that the mentioned areas for improvement could help provide more adequate results.

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APPENDIX

MEASURING CURRENCY EXPOSURE

The currency exposure can be assessed in terms of impact on portfolio volatility. We want to show the percentage difference of the portfolio variance denominated in the numeraire currency relative to the portfolio variance denominated in the currency basket. Let us denote R_p^{NOK} as the portfolio return denominated in the numeraire currency, while R_p^{BKT} is the portfolio return denominated in the currency basket. The currencies in the basket is weighted based on their weight in the total portfolio. Let us also denote X_{BKT}^{NOK} as the rate between the numeraire currency and the weighted currency basket. The return of the portfolio denominated is the numeraire currency is then

$$R_p^{NOK} = (1 + R_p^{BKT})(1 + X_{BKT}^{NOK}) - 1. \quad (16)$$

By calculating the variance of the currency basket return, we can get the variance of the numeraire return by

$$Var(R_p^{NOK}) = Var(R_p^{BKT}) + 2 \times Cov(R_p^{BKT}, X_{BKT}^{NOK}) + Var(X_{BKT}^{NOK}). \quad (17)$$

In this paper, we calculate the percentage differences of the portfolio variance based on a 24-month rolling window. The percentage difference is then

$$Pct.diff. = \frac{Var(R_p^{NOK}) - Var(R_p^{BKT})}{Var(R_p^{NOK})}. \quad (18)$$

EXHIBITS

EXHIBIT A – SUMMARY STATISTICS FOR THE FIRST SUB-SAMPLE

The first table provides summary statistics for the first sub-sample period that starts from January 2003 to June 2010. Panel A reports the per annum average 1-month interest rate and the standard deviation for each currency. Panel B reports the per annum monthly average excess return and monthly return on forwards and their corresponding standard deviation for each pair of currency.

PANEL A	NOK	USD	EUR	GBP	JPY	CHF	CAD	AUD
1-month interest rate p.a.								
Average	3.4032%	2.6104%	2.5191%	3.9773%	0.2888%	1.0190%	2.7662%	5.3667%
Std.dev.	1.5791%	1.8822%	1.2805%	1.8079%	0.2926%	0.9089%	1.3824%	1.1615%

PANEL B	NOK/ USD	NOK/ EUR	NOK/ GBP	NOK/ JPY	NOK/ CHF	NOK/ CAD	NOK/ AUD
Monthly currency return p.a.							
Average	-0.1592%	1.5190%	-1.3822%	4.2477%	3.0063%	5.0593%	5.2005%
Std.dev.	12.0987%	8.0173%	9.6801%	15.2480%	10.1018%	10.8399%	10.5596%
Monthly return on Forwards long position p.a.							
Average	-0.9634%	0.6385%	-0.8441%	1.0763%	0.6022%	4.3952%	7.1468%
Std.dev.	12.0045%	7.9494%	9.6724%	15.1383%	10.0032%	10.7740%	10.4718%

The second table provides the correlation matrix of pairs of the numeraire currency against foreign currencies against NOK for the first sub-sample. The correlation coefficients are based on currency returns.

	NOK/ USD	NOK/ EUR	NOK/ GBP	NOK/ JPY	NOK/ CHF	NOK/ CAD	NOK/ AUD
NOK/USD	1						
NOK/EUR	0.4524	1					
NOK/GBP	0.6049	0.4900	1				
NOK/JPY	0.7751	0.5199	0.4594	1			
NOK/CHF	0.5242	0.8270	0.4171	0.6466	1		
NOK/CAD	0.5512	0.3904	0.5036	0.3794	0.2658	1	
NOK/AUD	0.2274	0.5927	0.4538	0.1282	0.3456	0.5529	1

Exhibit B – Summary Statistics for the Second Sub-Sample

The first table provides summary statistics for the second sub-sample period that starts from July 2010 to December 2017. Panel A reports the per annum average 1-month interest rate and the standard deviation for each currency. Panel B reports the per annum monthly average excess return and monthly return on forwards and their corresponding standard deviation for each pair of currency.

Panel A	NOK	USD	EUR	GBP	JPY	CHF	CAD	AUD
1-month interest rate p.a.								
Average	1.5963%	0.3745%	0.1442%	0.5005%	0.0713%	-0.2981%	0.9478%	3.0721%
Std.dev.	0.6317%	0.3341%	0.4953%	0.1279%	0.0753%	0.4184%	0.2143%	1.0619%

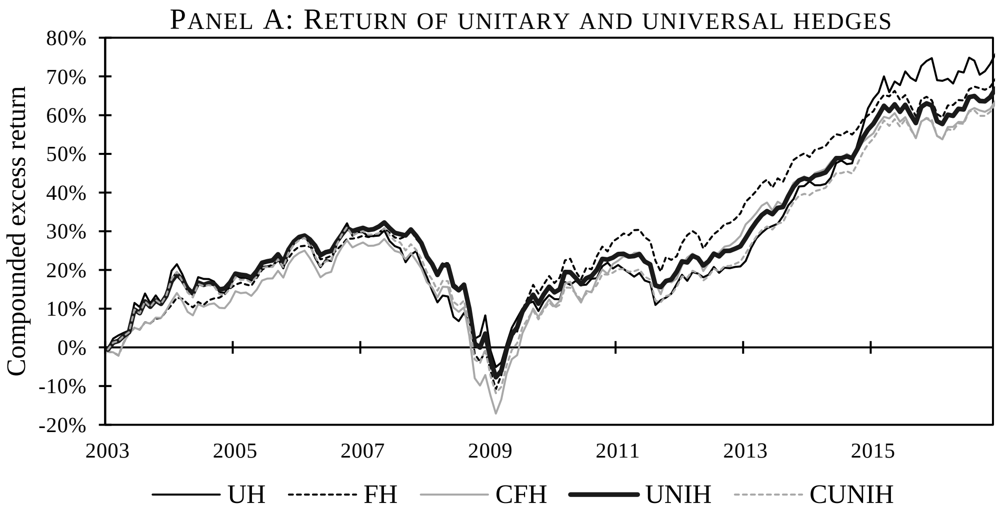
Panel B	NOK/ USD	NOK/ EUR	NOK/ GBP	NOK/ JPY	NOK/ CHF	NOK/ CAD	NOK/ AUD
Monthly currency return p.a.							
Average	3.8445%	3.0923%	2.2666%	0.7704%	4.9924%	1.1465%	2.4858%
Std.dev.	11.6306%	6.4962%	10.0167%	13.4686%	9.3416%	7.4851%	8.2952%
Monthly return on Forwards long position p.a.							
Average	2.5644%	1.6101%	1.1461%	-0.7600%	3.0291%	0.4779%	3.9784%
Std.dev.	11.6275%	6.4921%	10.0135%	13.4717%	9.3523%	7.4973%	8.2961%

The second table provides the correlation matrix of pairs of the numeraire currency against foreign currencies against NOK for the second sub-sample. The correlation coefficients are based on currency returns.

	NOK/ USD	NOK/ EUR	NOK/ GBP	NOK/ JPY	NOK/ CHF	NOK/ CAD	NOK/ AUD
NOK/USD	1						
NOK/EUR	0.5521	1					
NOK/GBP	0.7085	0.6108	1				
NOK/JPY	0.7167	0.4164	0.4378	1			
NOK/CHF	0.5468	0.4698	0.4514	0.5417	1		
NOK/CAD	0.6518	0.4573	0.6020	0.5125	0.3229	1	
NOK/AUD	0.3066	0.2657	0.3071	0.3714	0.3568	0.5396	1

Exhibit C – Conditional Versus Unconditional Strategies

The conditional strategies use interest rate differentials to forecast the currency movements during the next period. The method follows the well-known carry trade strategy. Panel A reports the continuously compounded excess return for the unhedged portfolio (UH) and the defined strategies: full hedge (FH), conditional full hedge (CFH), universal hedge (UNIH), and conditional universal hedge (CUNIH). All the returns are reported from January 2003 to December 2017.



Panel B reports the volatility measured in standard deviation based on the 24-month moving standard deviation. The first reported standard deviation is therefore in January 2005. The similar figures for the minimum variance hedges and the conditional optimal hedge are reported in Figure IV.

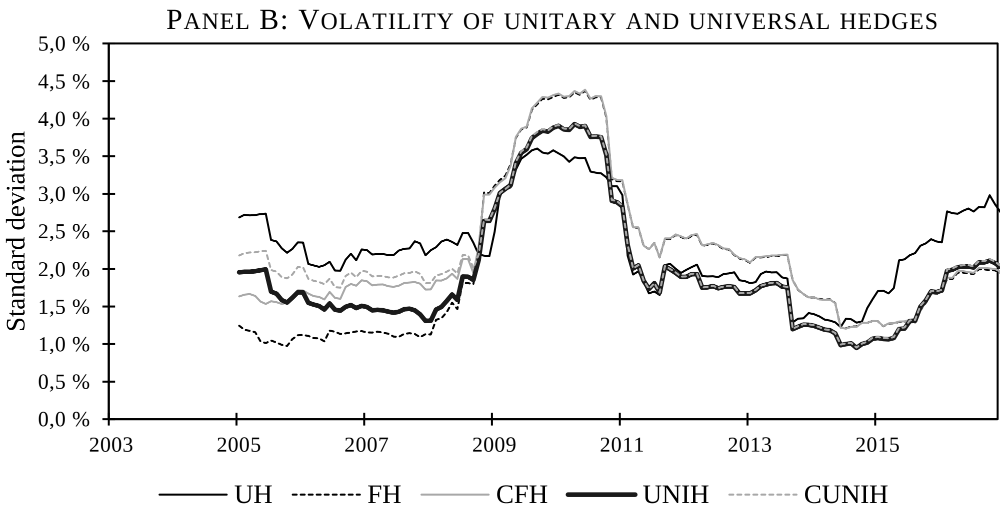


EXHIBIT D – CURRENCY RATE MOVEMENTS

The figure illustrates the currency rate movement for each currency pair against the numeraire currency for the full sample period from December 1997 to December 2017. The left vertical axis reports the currency rate for the US dollar, euro, British pound, Swiss franc, Canadian dollar and the Australian dollar. The right vertical axis reports the currency rate for the Japanese yen.