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Solvency II and Currency Risk

*An Assessment of Imposing Solvency Capital Requirements
from Currency Risk in Norway*

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Master thesis, Financial Economics

NORWEGIAN SCHOOL OF ECONOMICS

This thesis was written as a part of the Master of Science in Economics and Business Administration at NHH. Please note that neither the institution nor the examiners are responsible – through the approval of this thesis – for the theories and methods used, or results and conclusions drawn in this work.

1. Preface

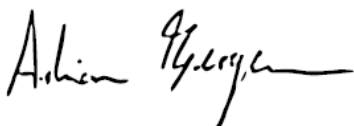
This master thesis was written as part of our Master of Science degree in Economics and Business Administration at NHH during the second semester of 2015. Our field of specialization in financial economics and interest in capital markets led to the topic of this thesis. The key issues discussed in this paper were first presented to us by Gabler Investment Management through the Finans|Bergen cooperation.

The thesis has been prepared in the Microsoft Office 365 ProPlus suite. In addition to MS Excel, MS Word and MS PowerPoint, we have had great use of the OneDrive cloud storage and file hosting system, enabling us to work in parallel on the same files. In addition, the use of the MS PowerPoint add-in Think-Cell has significantly facilitated the designing of graphical illustrations. Our data is extracted from the Bloomberg terminal provided by NHH.

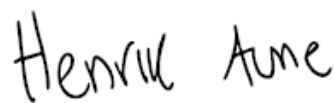
We would like to express our gratitude to all the people who have helped us in the process of writing this thesis. First, we would like to thank our supervisor Nikhil Atreya for quick feedback and supportive counselling; second, we would like to thank the people we have been in contact with in the various insurance companies for invaluable insight in the industry; and third, but not least, we would like to thank Nordea Markets for helpful assistance on the foreign exchange markets.

The findings and conclusions in this thesis are solely those of the authors.

Bergen, December 2015



Adrian Bergem



Henrik Kvalvåg Aune

2. Abstract

We assess the new EU directive for insurance companies, Solvency II, with regards to solvency capital requirement (SCR) from currency risk and its implications on risk management for Norwegian life insurers. The SCR is designed to offset losses during extreme market conditions. We question whether the direct adoption of the standard formula stipulated in the directive is reasonable for the Norwegian insurance market, as the Norwegian krone has historically had different characteristics than the euro. The parameter of interest is the input correlation factor between currencies and equities due to its impact on the SCR from currency risk through diversification effects. In the standard formula, this parameter is currently set to 0.25.

We conduct this assessment by creating a back-testing model with a sample period from 2003 to 2015 for international equity portfolios with various hedge ratios and computing the corresponding SCR. To ensure quality and relevance we have based our assumptions in the model on information from interviews with five major life insurers in Norway.

We find that a hedged portfolio underperforms its unhedged counterpart with respect to rate of return, volatility and, in particular, downside volatility. Downside volatility is what Norwegian life insurers mainly focus on because of the asymmetric payoff profile of their defined benefit pension products. By performing correlation and regression analyses, we find that the superior performance of the unhedged portfolio is caused by a predominantly negative correlation between the returns of the Norwegian krone (NOK) and international equity markets. This is due to the NOK's risk-on characteristics, meaning that the currency is negatively correlated with the risk perception in financial markets. We thus argue that adopting the input correlation parameter from the standard formula is questionable as it contradicts these historical market dynamics. Furthermore, we find that the SCR from currency risk is significantly dependent on the input correlation factor, meaning that Solvency II will incentivize Norwegian life insurers not to lower their hedge ratios, and by doing so, might work against its goal of increasing financial stability.

3. Contents

1. PREFACE	2
2. ABSTRACT	3
3. CONTENTS	4
3.1 LIST OF TABLES.....	5
3.2 LIST OF FIGURES	5
4. INTRODUCTION	7
4.1 BACKGROUND.....	7
4.2 KEY ISSUES	8
4.3 INTERVIEWS WITH THE INDUSTRY	8
4.4 STRUCTURE	8
5. THE NORWEGIAN LIFE INSURANCE BUSINESS	9
5.1 LIFE INSURANCE.....	9
5.2 MANDATORY OCCUPATIONAL PENSION SCHEMES	9
5.3 IMPLICATIONS OF OTP FUNDS MANAGEMENT FOR LIFE INSURERS	10
5.4 NORWEGIAN LIFE INSURERS' PORTFOLIO ALLOCATION	11
6. INTERNATIONAL EQUITY PORTFOLIOS AND HEDGING CURRENCY RISK	13
6.1 INTERNATIONAL EQUITY PORTFOLIOS.....	13
6.2 HEDGING CURRENCY RISK	14
6.3 PERFORMANCE MEASURES FOR THE HEDGING DECISION	16
6.4 CURRENT PRACTICES FOR CURRENCY RISK MANAGEMENT BY NORWEGIAN LIFE INSURERS	19
6.5 REVIEW OF PREVIOUS RESEARCH	20
7. SOLVENCY II	22
7.1 SOLVENCY CAPITAL REQUIREMENT.....	22
7.2 TECHNICAL SPECIFICATIONS	23
8. DATA	27
8.1 DATA DESCRIPTION	27
8.2 DESCRIPTIVE STATISTICS OF THE DATA	28
8.3 DATA ISSUES.....	29
9. METHODOLOGY	31

9.1	AN OVERVIEW OF THE MODEL	31
9.2	CONSTRUCTING THE PORTFOLIO	32
9.3	CONSTRUCTING THE SCR PORTFOLIO	33
10.	RESULTS AND ANALYSIS	36
10.1	ANALYSIS OF HEDGING CURRENCY RISK WITH NOK AS A BASE CURRENCY	36
10.2	ANALYSIS OF THE SOLVENCY CAPITAL REQUIREMENT FROM CURRENCY RISK.....	48
11.	CONCLUSION	51
12.	REFERENCES.....	52
13.	APPENDIX	56
13.1	DIRECT COST OF HEDGING.....	56
13.2	A COMPREHENSIVE OVERVIEW OF THE VARIABLES IN THE MODEL.....	57
13.3	FOREIGN EXCHANGE RATES REGRESSIONS	62
13.4	SENSITIVITY ANALYSIS OF REBALANCING BOUNDARY	63

3.1 List of Tables

TABLE 1	RETURN AND STANDARD DEVIATION FOR THE STOCK INDEXES.....	28
TABLE 2	PORTFOLIO PERFORMANCE FOR THE ENTIRE SAMPLE PERIOD AND THE PERIOD BEFORE THE RECENT DEPRECIATION.....	36
TABLE 3	OPTIMAL HEDGE RATIO CALCULATED AS THE $1 - w_c, j *$ (THE OPTIMAL CURRENCY EXPOSURE) FROM EQUATION 25 FOR DIFFERENT CORRELATION PARAMETERS	42
TABLE 4	PROPERTIES OF THE FOREIGN EQUITY INDEXES AND FOREIGN CURRENCY AGAINST THE NOK	42
TABLE 5	REGRESSION WITH USDNOK AS DEPENDENT VARIABLE AND INTEREST RATE SPREAD, OIL PRICE AND CVIX AS INDEPENDENT VARIABLES.....	46
TABLE 6	SCR AS PERCENTAGE OF TOTAL PORTFOLIO FOR DIFFERENT HEDGE RATIOS AND CORRELATION PARAMETERS.....	49
TABLE 7	SELECTED SUMMARY STATISTICS OF THE BID-ASK SPREADS FOR 6M FORWARDS	56
TABLE 8	REGRESSION OUTPUT FOR DRIVERS OF THE NOK	62
TABLE 9	SENSITIVITY ANALYSIS OF VARIOUS PERFORMANCE MEASURES WITH RESPECT TO THE REBALANCING BOUNDARY	63

3.2 List of Figures

FIGURE 1	PROFIT FUNCTION FOR DEFINED BENEFIT PRODUCTS	10
FIGURE 2	ALLOCATION IN GROUP PORTFOLIO FOR MAJOR LIFE INSURANCE FIRMS IN NORWAY AS OF 31.12.2014.....	12
FIGURE 3	OTC FOREIGN EXCHANGE TURNOVER BY INSTRUMENTS IN APRIL 2013	14
FIGURE 4	ALLOWED AND ACTUAL FUNDING OF OWN FUNDS	25

FIGURE 5 INDEXED RETURNS OF STOCK INDEXES 2003-2015	28
FIGURE 6 FOREIGN EXCHANGE SPOT RATES.....	29
FIGURE 7 INDEXED HEDGED AND UNHEDGED INTERNATIONAL EQUITY PORTFOLIOS DENOTED IN NOK	36
FIGURE 8 DIFFERENCE IN SEMIANNUAL RETURN BETWEEN THE HEDGED AND UNHEDGED PORTFOLIO.....	37
FIGURE 9 FORWARD RATES AND ACTUAL SPOT RATES	38
FIGURE 10 DIFFERENCE IN SEMIANNUAL VOLATILITY BETWEEN THE HEDGED AND UNHEDGED PORTFOLIO	38
FIGURE 11 DIFFERENCE IN SEMIANNUAL DOWNSIDE VOLATILITY BETWEEN THE HEDGED AND UNHEDGED PORTFOLIO	39
FIGURE 12 100-DAY ROLLING EQUITY-CURRENCY CORRELATION FACTOR FOR THE EUROZONE AND THE US.....	43
FIGURE 13 100-DAY ROLLING EQUITY-CURRENCY CORRELATION FACTOR FOR THE UK AND JAPAN	43
FIGURE 14 AVERAGE HISTORICAL CORRELATION VS CORRELATION FROM WHERE OPTIMAL HEDGE RATIO = 0%	44
FIGURE 15 TURBULENCE MEASURED BY THE INDEXES FOR IMPLIED VOLATILITY IN EQUITIES (VIX) AND CURRENCIES (CVIX).....	46
FIGURE 16 RELATIONSHIP BETWEEN SCR FROM CURRENCY RISK AND THE HEDGE RATIO.....	48

4. Introduction

4.1 Background

Norwegian life insurers manage a considerable share of Norwegian pensions in addition to premiums from insurance policies. Even though a relatively modest portion of the pensions is invested in equity, it currently amounts to a combined value of approximately 262 bnNOK (31bnUSD) (Finans Norge, 2015).¹ The majority of the equity investments is allocated abroad, giving rise to the need for currency risk management. Following the sharp depreciation of the NOK during 2014, currency risk management has attracted attention in Norway. Insurance companies are among the largest investors in financial markets and constitute a cornerstone in the national economy. Their stability is thus of vital importance to the smooth-functioning of financial markets.

A new directive called Solvency II, devised by the European Commission to promote financial stability in the insurance market, is to be implemented the 1st of January 2016. This directive will fundamentally alter how the insurance companies within the EEA report, quantify and manage risk. A central component of the directive will be the reforming of capital adequacy requirements. One of these requirements, called solvency capital requirement (SCR), is designed to enable insurance companies to withstand potential losses from, among other things, unhedged currency positions in extreme market downturns. In other words, an open position in currency demands more capital set aside than a hedged currency position. This discrimination is lessened by input correlation parameters in the SCR model through diversification benefits. In this thesis, we will assess the following key issues:

¹ Sum of equity investments in the group portfolio. Computed from FinansNorge's most recent report "*Market share: Final Numbers and Accounting Statistics*".

4.2 Key Issues

- 1) Is the extent of discrimination imposed by Solvency II, with regards to solvency capital requirements for unhedged as opposed to hedged currency positions, reasonable for the Norwegian market?
- 2) What implications does the input correlation factor in the SCR model, which in the standard formula is currently set to 0.25, have for the currency risk management of Norwegian life insurers?

4.3 Interviews with the Industry

An important part of the research leading up to our discussions and conclusions is the interviews we had with key people in major Norwegian life insurers. The industry professionals we have been in contact with are the following:

- Anders Skjævestad Chief Executive Officer DNB Liv
- Nina Fiskaaen Chief Investment Officer Nordea Liv
- Tørres Trovik Head of Investments at Storebrand
- Christian Parelius Chief Investment Officer Sparebank1 Forsikring
- Svein Stokke Chief Risk Officer at KLP

The purpose of our interviews was to understand the life insurer business model and ensure that our analyses are based on realistic assumptions. Furthermore, through the interviews we have achieved a greater insight in their investment and hedging practices, in addition to getting valuable reflections on the key issues. We believe the practical approach this gives us adds significant value to our conclusions and results.

4.4 Structure

We begin by introducing the reader to the various concepts relevant to the assessment, namely the Norwegian life insurance business, theory on international equity portfolios and currency hedging, and the Solvency II directive. Next, we present an overview of the data selection and the methodology for the back-testing model. Finally, we discuss the results and present correlation and regression analyses to make further inferences from our findings.

5. The Norwegian Life Insurance Business

In this section, we will go through the key elements of the Norwegian life insurance business that are relevant for this thesis.

5.1 Life Insurance

Life insurance is a contract between the life insurance company and the customer. The price of the product, the life insurance premium, is paid by the customer in exchange for a designated lump sum pay-out in case of death or disablement, depending on the contract. Life insurers also engage in the business of managing pension funds.

5.2 Mandatory Occupational Pension Schemes

In Norway, the pension a retired employee receives is made up of three components; private savings, employer contribution and the National Insurance. Mandatory employer contribution, also called occupational pension, was imposed in Norway in 2006 through the Mandatory Occupational Pension (OTP) Act.² The act obliged most employers to have an OTP scheme for all employees. The purpose was to create a system that ensures adequate pension for everyone. The National Insurance, on the other hand, is a national welfare system which applies to all Norwegian citizens. The pension provided by this system is the annually accumulated 18.1 percent of the salary (NAV, 2015).³

There are two sorts of OTP schemes in Norway; defined contribution and defined benefit. In the former scheme, the employer deposits a fixed amount each year, usually a percentage of the salary, in a pension fund.⁴ The deposits and the accumulated returns will make up the employee's pension. In the latter scheme, the pension benefit is pre-set. This means that the retired employee will receive a pension of usually between 60-70 percent of the final salary. The defined benefit will constitute the share of this pension that the National Insurance does

² The abbreviation comes from the Norwegian word for mandatory occupational pension, obligatorisk tjenestepensjon.

³ Only the salary up to 7.1 G is included in this calculation. G is an amount set and regulated by the National Insurance, currently set to 90,068 NOK.

⁴ The minimum requirement by law is 2 percent.

not cover. In order to guarantee such a pension plan, the employer deposits a yearly premium based on the employee's age and salary.

5.3 Implications of OTP Funds Management for Life Insurers

Life insurers offer management of both defined contribution and defined benefit funds. The important difference between the two pension schemes is the allocation of risk. In a defined contribution scheme, the employee bears all the risk, whereas in a defined benefit scheme, as the future pension payout is pre-set, the employer bears all the risk. In the case of a defined benefit scheme, the risk is reallocated by engaging a life insurer in the pension management. The employer will pay an annual premium to the life insurer who in return needs to satisfy pre-set annual guaranteed rates of return. The potential negative deviations from the annual settlements of the guaranteed rates are covered by the life insurers. Furthermore, the return in excess of the guaranteed rate mostly or entirely goes to the employee, rather than the life insurer. The employee receives a share of between 80 and 100 percent of the return, depending on the pension product. The combination of bearing all the downside risk, but having a mere 20 percent of the upside, creates an asymmetric payoff function for the life insurer, illustrated in Figure 1. The reason why the function is flat in a certain interval below the guaranteed rate is that insurance firms hold provisions for not meeting the annual guaranteed rate.

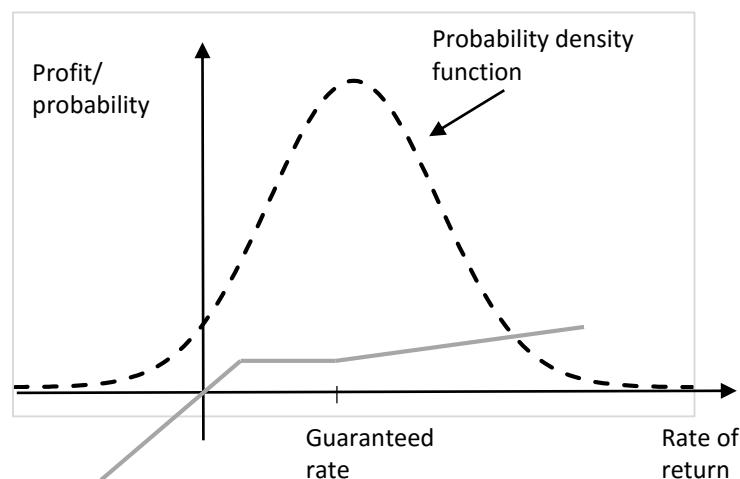


Figure 1 Profit function for defined benefit products

Guaranteed interest rate products are obviously poor assets in the current low-interest rate environment. Their origination dates back to periods with high-interest rate environments where life insurers easily could achieve 3-4 percent return by mostly investing in low-risk government bonds. Today these products represent a significant liability for life-insurers.

5.4 Norwegian Life Insurers' Portfolio Allocation

The Insurance Act of 2005 specifies in § 9-7 that insurance companies are obliged to classify their portfolios into three categories: the group portfolio, the unit-linked portfolio and the company portfolio (Finanstilsynet, 2013). The first two are client portfolios while the last primarily consists of the firm's equity. The big picture is that the group portfolio consists of funds from defined benefit pensions and insurance products, whereas the unit-linked portfolio consists of funds from defined contribution pensions. The only category of interest, based on the scope of this thesis, is the group portfolio. The reason is that this is the only category generating market risk for the life insurer leading to capital requirements from currency exposure (covered more in detail in section 7). As we have seen, the risk from the liabilities from these products is borne entirely by the life insurer, as opposed to defined contribution.

Due to the asymmetric payoff profile, the goal of the group portfolio investments is merely to reach the guaranteed rates and limit downside risk as much as possible. Consequently, even though the duration of the liabilities for this portfolio is long, only a small share is allocated in risky assets. In Figure 2 we see that the equity share varies from 5 to 20 percent of the portfolio (2014 annual reports).⁵ The majority of this, usually between 2/3 and 3/4, is allocated internationally (Interviews with industry professionals, 2015).

⁵ KLP's high equity share is caused by the properties of their guaranteed rate products in the group portfolio. Unlike the other life insurers they hold public defined benefit pensions where the downside is owned by the respective municipalities. Thus, they are able to have more risk in their portfolio compared to the other life insurers in Norway.

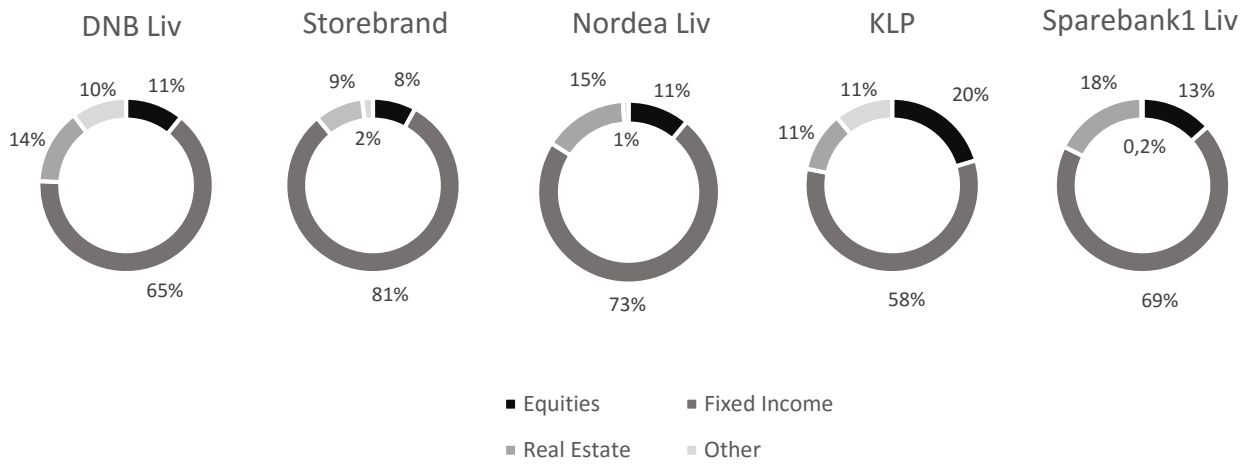


Figure 2 Allocation in group portfolio for major life insurance firms in Norway as of 31.12.2014

6. International Equity Portfolios and Hedging Currency Risk

This section comprises a collection of concepts to understand Norwegian life insurers' hedging policies along with previous research on the topic.

6.1 International Equity Portfolios

When an investor buys international equity denoted in a foreign currency, the risk and return profiles will differ from those of an investment denoted in the investor's base currency. In addition to the equity return, an unhedged international investor will see the portfolio return fluctuate in lockstep with the variations of the exchange rates between the local and foreign currency. For an unhedged portfolio of foreign equities with NOK as the base currency, the NOK rate of return will be given by 3 elements; the local equity return, the foreign exchange (FX) return and the cross-return. The cross-return is the FX return on the local equity return.

The equity return is given by $r_{i,t} = p_{i,t}/p_{i,t-1} - 1$, where p is the equity security in local currency. The forward exchange return, e , is positive if the local currency appreciates against the base currency. This is given by $e_{i,t} = s_{i,t}/s_{i,t-1} - 1$, where s is the spot rate for currency i at time t . Formally, the NOK rate of return for investing in the i^{th} foreign equity market and for a holding period from $t-1$ to t is given by:

$$r_{i,t}^{NOK} = (1 + r_{i,t})(1 + e_{i,t}) - 1 \quad \text{Equation 1}$$

$$r_{i,t}^{NOK} = r_{i,t} + e_{i,t} + r_{i,t}e_{i,t} \quad \text{Equation 2}$$

$$r_{i,t}^{NOK} = \text{Equity return} + \text{FX return} + \text{CrossReturn} \quad \text{Equation 3}$$

The equity investment value in NOK at time t , denoted by the capital letter P , is thus given by:

$$P_{i,t} = P_{i,t-1} * (1 + r_{i,t} + e_{i,t} + r_{i,t}e_{i,t}) \quad \text{Equation 4}$$

The value of the total unhedged portfolio at time t , is then the sum of the different equity investments:

$$\text{Portfolio}_t = \sum_{i=1}^N P_{i,t} \quad \text{Equation 5}$$

6.2 Hedging Currency Risk

Fluctuations in the exchange rate can potentially have a significant impact on the international portfolio performance, given that the currency regime is free-floating. For an investor with assets and liabilities denoted in different currencies, the currency risk may be perceived as undesired volatility.

There are various methods for managing currency risk. Figure 3 shows the turnover of different foreign exchange derivatives commonly used for hedging purposes (Bank for International Settlements, 2013). These non-standardized instruments are traded over the counter through FX dealers.

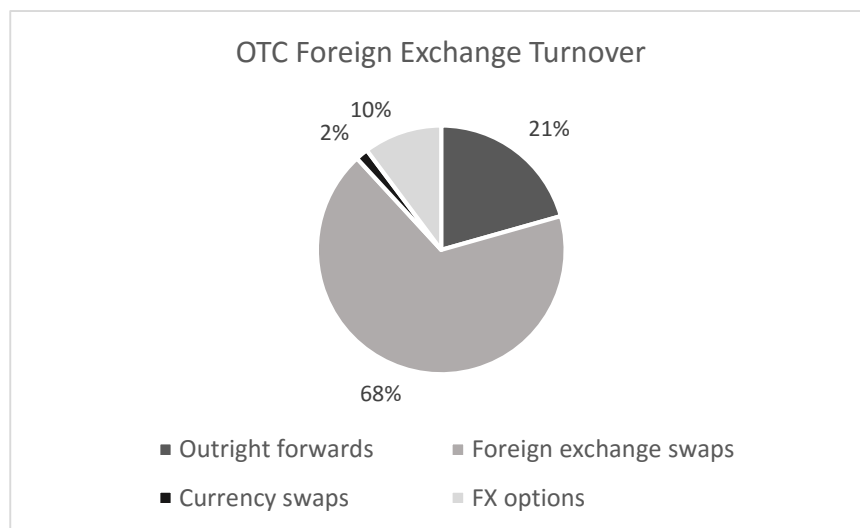


Figure 3 OTC foreign exchange turnover by instruments in April 2013

Outright forwards are contracts involving the exchange of two currencies in the future to an agreed rate. The only exchange of cash flows is done on the settlement date. The agreed rate, called forward rate, is set on the time of the contract. The covered interest rate parity states that this rate is given by the spot rate and the interest rates for the two currencies:

$$f = s * (1 + r_1) / (1 + r_2), \quad \text{Equation 6}$$

f = forward rate

s = spot rate

r_1 = interest rate for the base currency

r_2 = interest rate for the quote currency

Traders of arbitrage opportunities quickly eliminate deviations from this parity.⁶ (Bekaert & Hodrick, 2014, p. 187)

FX swaps are transactions involving the exchange of principals of two currencies on a specific date (the short leg), and then a reversed exchange of principals on a date further in the future (the long leg). The foreign exchange rates for the two exchanges of principals are both set on the signing of the contract. The short leg can either be a spot transaction or a shorter forward contract than the long leg. In other words, FX swaps involve the buying and selling of forward contracts and, for some swaps, spot transactions. Currency swaps are similar, but also include the exchanges of coupon payments between the short leg and the long leg. (Bank for International Settlements, 2013)

Foreign exchange options (FX options) are contracts that give the right to buy or sell a given currency to a specified FX rate against another currency during a certain period (Bank for International Settlements, 2013). The main difference between FX options and the other instruments is the right, but not the obligation, to execute the contract. In other words, FX options give another level of flexibility to the client.

Currency hedging comes at a cost. The direct cost of hedging is the bid-ask spread of hedging instruments, charged by the FX dealer. The spread is the difference between the rate the bank is willing to buy (bid) and the rate the bank is willing to sell (ask) the base currency. The spread is generally higher for the less liquid currencies, like the NOK, and for instruments with longer maturities. There are also indirect costs of hedging such as paying and surveilling employees to perform hedging activity.

Derivatives enable investors to control currency risk. However, it is important to be aware of that by locking in the future exchange rate one misses out potentially significant currency returns. For example, the drop in the oil price causing the NOK to plummet against all G10 currencies⁷ during the second half of 2014, led to significant missed returns for a hedged portfolio in that period. Similarly, during the Global Financial Crisis (GFC) of 2007-2008, we witnessed another worthy depreciation of the NOK. Any unhedged Norwegian funds invested

⁶ For a more thorough analysis on the pricing of forward contracts, see Fama (1984).

⁷ The G10 currencies are the most traded currencies in the world.

abroad would have suffered less of an equity loss during the period due to a simultaneous depreciation of the NOK.

6.3 Performance Measures for the Hedging Decision

Holding foreign currency will have an impact on both the risk and return of an international portfolio. It is important to assess what the goal of the currency risk management is. Is the goal to capitalize on return-awarding strategies or to minimize risk? The different strategies often require different risk management practices.

We will in this section go through the main performance measures that we believe are applicable for portfolio evaluation for the purpose of this thesis.

Return

One strategy for the currency decision is to use currency as a source of alpha (risk-adjusted excess return). Research has shown that currency movements follow a random walk and are extremely difficult to predict (LaBarge, Thomas, Polanco, & Schlanger, 2014). An alternative explanation of the price movements of currency is that it follows a mean-reversion trend. The mean-reversion theory states that over time, the exchange rate will tend to move back to its long-term fair value.⁸ Regardless of different price theories, the ability to predict currency movements, at least in the short term, is highly debatable.

We already touched upon the pricing mechanisms of forward contracts in section 6.2 by introducing the covered interest rate parity. Whereas the covered interest rate parity holds in well-developed financial markets, empirical studies have so far struggled to prove the validity of the uncovered interest rate parity (UIRP). If one borrows in a country with low interest rates and places the funds in a country with higher interest rates, the UIRP states that the amount earned on the interest rate differential will be offset by an equivalent change in the exchange rate. If this were to be the case, the unbiasedness hypothesis would also hold, meaning that

⁸ See Cheung & Lai (1994) and/or Sweeney (2000) for further studies on mean reversion in exchange rates.

forward rates are unbiased predictors of future spot rates.⁹ Carry trade is a common strategy for, among others, hedge funds that capitalize on the uncovered interest rate parity not holding.

One measure for evaluating ex-post return is the geometric average return. The geometric return differs from the standard arithmetic average in that it controls for compounding. Thus, when evaluating the ex-post performance of portfolios, the geometric average provides a better picture of the realized performance than the arithmetic average. In our thesis the return measure will be the geometric average unless stated otherwise.

The formula for geometric average return for a security, r_g , is given by:

$$r_g = \left(\prod_{t=1}^T (1 + r_t) \right)^{\frac{1}{T}} - 1 \quad \text{Equation 7}$$

T = number of observations

r_t = return at time t

Risk

Volatility

As mentioned previously, an unhedged portfolio will hold currency risk. When discussing risk, it is essential to clarify which measure of risk to consider.

Harry Markowitz developed modern portfolio theory (1952) which has been widely adopted by scholars and practitioners. One of the key concepts in his theory is that the most efficient portfolio is the one that yields the best mean return-variance relationship (MV). Thus, the variance, or the squared standard deviation, commonly referred to as the volatility of returns, has been the preferred risk measure in constructing and evaluating portfolios (Hoe, Hafizah, & Zaidi, 2010). We will in this thesis use the standard deviation as the definition of volatility. The standard deviation is a measure of how much the return of a portfolio deviates from its average over time and is formally given by:

⁹ For more information on the unbiasedness hypothesis, see Levi (2005).

$$\sigma_p = \sqrt{\frac{1}{T} \sum_{t=1}^T (r_t - \bar{r})^2}$$

Equation 8

$r_t =$ return at time t

$\bar{r} =$ average arithmetic return

Downside Volatility

When we look at the standard deviation, we do not differentiate between volatility stemming from positive or negative returns. The semideviation, on the contrary, is a measure that captures the volatility of the rate of return below a specific threshold. In later years, Markowitz himself advocated for the use of semideviation in portfolio optimization rather than the variance (Markowitz, 1991, p. 194). Markowitz also stated that semideviation represents a better risk measure than standard deviation for an investor who worries about underperformance rather than outperformance (Markowitz, Todd, Xu, & Yamane, 1993). Remembering the asymmetric payoff profile for a Norwegian life insurer from defined benefit pensions funds, this measure is fitting for our case.

In our model we set the threshold in the semideviation equal to zero. An alternative threshold could be the minimum daily rate of return in order to meet the annual guaranteed rate. However, this rate would have been close to zero, and more of a disturbing factor than practical. Furthermore, we have chosen zero as it is a more familiar and relatable threshold in portfolio management. This enables the life insurer to measure the volatility of negative rates of return.

The semideviation, $\tilde{\sigma}_p$, is given by:

$$\tilde{\sigma}_p = \sqrt{\frac{1}{T} \sum_{t=1}^T [\text{Min}(r_t - \tilde{r}, 0)]^2}$$

Equation 9

$\tilde{r} =$ The treshold for return

6.4 Current Practices for Currency Risk Management by Norwegian Life Insurers

The major Norwegian life insurers mostly have a similar approach to their currency risk management of the group portfolio.¹⁰ The asymmetric payoff structure of the guaranteed rate products, described in section 5.3, reduces their willingness to take on risk, which is reflected in their low allocation in risky assets. This relationship is further displayed in the life insurers' currency risk management. As the rates of return are a result of the value of the portfolio at the end of the year, their goal is to minimize the risk of the return being affected by an unfavorable foreign exchange rate movement. In statistical terms, one could say that their goal is to limit annual downside volatility of returns. In the pursuit of this goal, they all operate with high hedge ratios, ranging from 85 to 100 percent. The hedge ratios are mainly static and the hedging policies are rarely changed. (Interviews with industry professionals, 2015).

Norwegian life insurers generally do not capitalize on carry trade or other return-awarding strategies in the decision of hedging the currency exposure from their international equity investments in the group portfolio. For other asset classes in their group portfolio, the currency risk management is somewhat different. Some of the industry players we have been in contact with impose return-awarding currency hedging strategies for their international investments in real estate. For fixed income, as the volatility of currency is generally higher than the volatility of bonds, it is common to fully hedge these positions (Interviews with industry professionals, 2015). This is in line with what research on the topic suggests.¹¹

The conservative approach to currency risk management of Norwegian life insurers is reflected in their choice of hedging instruments. FX swaps and forward contracts are the most popular derivatives, whereas the use of FX options is scarce. The most common maturities of the forward contracts are 3 months and 6 months. (Interviews with industry professionals, 2015)

¹⁰ As a reminder, the group portfolio consists of funds from defined benefit pension and insurance products and is hence subject to meeting annual guaranteed rates.

¹¹ See LaBarge, Thomas, Polanco, & Schlanger, 2014.

6.5 Review of Previous Research

In this section, we will review previous research on the topic, both conducted by scholars and industry players. We begin by going back to the origins of international portfolio theory in order to give the reader a more complete overview on this area of research.

It took 16 years for the international application of Markowitz' (1952) concepts of modern portfolio analysis to take place. In 1968, Grubel (1968) argued that international diversification of an investment portfolio constituted a considerable contribution to world welfare gains. This triggered a series of studies on international diversification in the 1970s¹², assessing whether adding foreign assets to a domestic efficient portfolio improves the risk-return profile. Even though these papers at the time collectively made up convincing evidence for international diversification, they were conducted on an ex-post (in-sample) basis. The distinction between ex-post and ex-ante (out-of-sample) matters in these studies due to the estimation of weights for various types of portfolios.¹³ Due to the nature of these assumptions, the results from these studies might not hold in a more realistic context.

During the 1980s, the first ex-ante studies were published. In the paper "Exchange Rate Uncertainty, Forward Contracts, and International Portfolio Selection" (1988) Eun and Resnick develop efficient international portfolio selection strategies taking flexible exchange rates into account. They have two approaches on reducing currency risk, namely currency diversification and hedging through forward contracts. First, their findings show that exchange rate risk to a large extent is nondiversifiable due to the high integration of the foreign exchange markets. Second, they find that the hedged strategies outperform their unhedged counterparts on a risk-return basis.

At this point, most academic papers on international diversification had focused on dollar-based investors, or other large capital markets. In their paper, Bugár and Maurer (2002) take the viewpoint of a Hungarian investor compared to a German investor in their study of the effect of global investments and currency hedging. The purpose was especially to investigate the effect of a base currency characterized by a smaller capital market. Their findings was that

¹² See Levy and Sarnat (1970), Solnik (1974) and Lessard (1976).

¹³ Commonly used theoretical portfolios are the mean-variance portfolio (MVP) and tangency portfolio (TG).

a fully hedged portfolio outperformed an unhedged portfolio on a risk-return basis from both a Hungarian and a German perspective, on an ex-ante basis.

Even though academic research has come close to some of our key issues, the market dynamics for the Hungarian forint before 2002 were inarguably different from the more recent market dynamics for the Norwegian Krone. Next, we will present empirical research conducted by Vanguard, one of the largest investment companies worldwide, that applies to our context.

In two empirical studies, LaBarge (2010) and LaBarge et al (2014), finds that in order to minimize portfolio risk one should adjust the hedge ratio based on the sign and strength of the equity-currency correlation. They study the ex-ante optimal hedge ratio for five major currencies. For all currencies but the Australian dollar (AUD), the optimal hedge ratio is between 50 and 100 percent. Their findings show that due to the negative correlation between the return of the AUD and foreign equity markets, the Australian investor's portfolio experiences less risk and greater return by not hedging the currency risk. Interestingly, the AUD shares some of the same characteristics as the NOK, such as its link to commodity prices.

7. Solvency II

Solvency II (2009/138/EC) is a directive devised by the European Commission which will reform the insurance regulations in EU and EEA through the implementation of common risk management standards and, in particular, capital adequacy requirements. The intention for the directive is to minimize default risk of insurers and thereby promote financial stability in Europe. Whereas Solvency I required insurers to set capital aside purely based on the volume of their premiums, Solvency II is based on the risk acceptability concept. This means that the capital adequacy requirements will be based on the amount and different sorts of risk the insurer is exposed to. Moreover, Solvency II values assets and liabilities to market value in order to better reflect the underlying risk. (Deutsche Bank, 2011)

Like the legal framework for European banking regulation (Basel II/III), Solvency II is based on three pillars representing the main objectives for the directive (Deutsche Bank, 2011):

Pillar 1 - Financial Requirements: concerns the quantitative capital adequacy requirements. These requirements consist of the minimum capital requirement (MCR) and the regulatory solvency capital requirement (SCR).

Pillar 2 - Governance and Supervision: concerns the qualitative requirements for risk management, supervision and internal control.

Pillar 3 - Reporting and disclosure: concerns measures to ensure market discipline through rules for transparency and reporting.

In Norway, Solvency II is set to be implemented the 1st of January 2016 through chapter 14 in a new Norwegian law concerning the financial sector (Lundqvist, 2015). The Norwegian Financial Security Agency (Finanstilsynet) has developed a stress test for life insurers and pension funds with the intention to prepare for the implementation of Solvency II.

7.1 Solvency Capital Requirement

We will focus on the SCR defined in Pillar 1. The SCR is the amount of capital an insurer has to set aside to be at least 99.5 percent certain that it will be able to meet its obligations during the next 12 months (European Parliament and Of the Council, 2009, pp. 13, Article 64). In other words, Solvency II intends to set the probability of yearly default to 0.5 percent or less

(KPMG, 2011). Technically, this is given by the insurer's Value-at-Risk¹⁴ (VaR) with a confidence level of 99.5 percent over one year. If the insurer does not comply with the SCR, regulatory authorities will monitor the company and ensure that the requirements are met in due course (Deutsche Bank, 2011).

The SCR is calculated based on a number of different risk modules, namely operational risk, credit risk, life underwriting risk, non-life underwriting risk, health underwriting risk, intangible assets risk and market risk. Market risk is what we will focus on. This risk arises from the volatility level or volume of the financial instruments held by the insurer and consists of the following sub-modules; equity risk, currency risk, interest rate risk, real estate risk, spread risk, concentration risk and illiquidity risk (EIOPA, 2014). Several quantitative impact assessments (QIS) have been conducted by the EIOPA¹⁵ on behalf of the EU Commission. The most recent one, published in March 2011 (QIS5), found that the market risk is estimated to account for 70 percent of the total capital requirements for life insurers (EIOPA, 2011).

The European Commission has created a standard formula for the computation of SCR entailing all sorts of different input parameters and guidelines. However, insurers are allowed to devise their own customized internal models whose purpose is to better reflect the companies' risk profiles. The internal models are dependent on the approval of regulatory authorities which requires extensive documentation and reporting. In Norway, all the major life insurance companies will initially adopt the standard formula. (Interviews with industry professionals, 2015)

7.2 Technical Specifications

The stand-alone SCR derived from the different risk modules is computed by adjusting the exposure towards these risks with appropriate, pre-set stress factors. The stress factors are set to correspond to the potential losses in a 99.5 percent VaR scenario. The total SCR from market risk is computed by adding these stand-alone SCRs together and controlling for

¹⁴ Value at Risk (VaR) is a common measure of downside risk and reflects the potential loss for a given probability. For more information on VaR see (Jorion, 2006)

¹⁵ European Insurance and Occupational Pensions Authority

diversification arising from correlation between these risks. As these correlations apply to the 99.5 VaR situation, they are meant to reflect dependencies across risk factors in the tail of the correlation distribution. The diversification approach is built on the assumption that the actuarial risks will most likely materialize at different points in time. In order to compute the total SCR from all sources of risk, also the diversification from correlation between credit risk, insurance risk and market risk is accounted for.¹⁶ (EIOPA, 2014)

Formally, the SCR will be determined by the following formula:

$$SCR = \sqrt{\sum_{i,j}^{N} Corr_{i,j} * L_i * L_j} \quad \text{Equation 10}$$

$Corr_{i,j}$ = entries of the correlation matrix $Corr$

$L_{i,j}$ = capital requirements from the various risk modules

The correlation matrix $Corr$ set by the standard formula treats all instruments within the risk modules equally. For example, for currency risk, NOK is assumed to correlate with US stocks the same way the EUR does. The parameter of central importance in this thesis is the correlation between currency risk and equity risk, which is set to 0.25.

In Solvency II capital is defined as “own funds” that is again divided into three tiers. The tiers differs in availability and loss absorption properties. Tier 1 is the highest quality and is required to momentarily absorb losses if needed. Tier 2 and 3 consist of capital that is more sub-ordinated than Tier 1 and thus have lower demands on quality. Figure 4 shows the allowed compared to the actual allocation of own funds. Tier 1 capital is required from the EU commission to amount to minimum 50 percent of the SCR, while Tier 2 and Tier 3 capital is restricted to 50 and 15 percent respectively (EIOPA, 2014). QIS5 suggests that the financing of the own funds in practice largely differs from the requirements. The report states that 93 percent of the own funds in the participating companies will be Tier 1 capital, of which 96 percent is equity and 4 percent is subordinated debt and other hybrid capital instruments. In other words, almost all of the own funds will be funded by equity.

Furthermore, EIOPA remarks that the hybrid capital instruments used will have to have

¹⁶ No diversification effect is assumed by the standard formula to originate from correlations between the operational risk and the other risk modules.

similar loss absorbing capabilities as the equity. Consequently, they expect the differences in the cost of equity and allowed external funding to abate going forward (EIOPA, 2011).

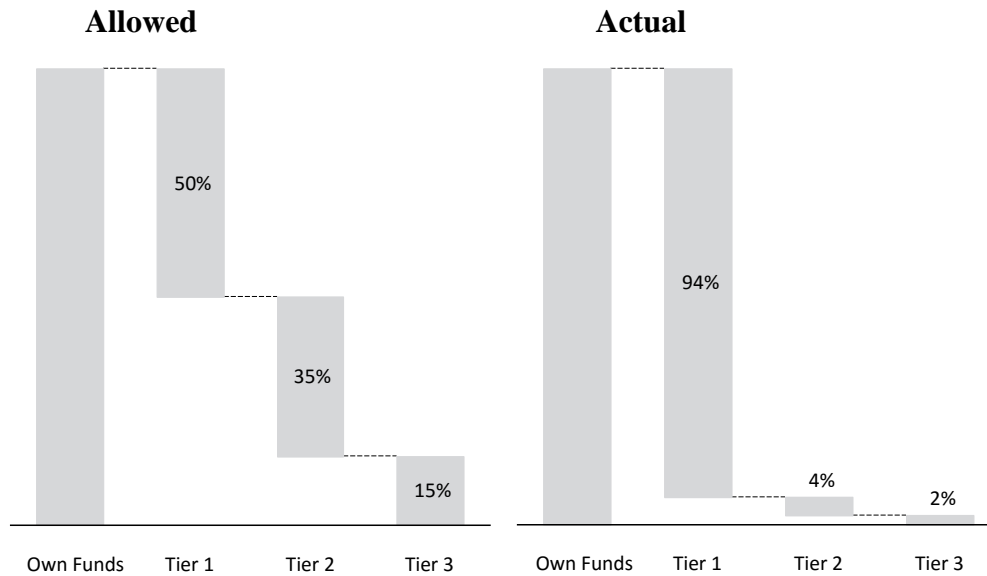


Figure 4 Allowed and actual funding of own funds

Next, we will present the technical specifications for equity risk and currency risk.

7.2.1 Equity Risk

The 99.5 percent VaR loss due to equity investments within the EEA and OECD, L_E , is given by (EIOPA, 2014, p. 112):

$$L_E = 0.39 * V_E - \Delta D_{E,-39\%} \quad \text{Equation 11}$$

$V_E =$ Market value of the equity position

$\Delta D_{E,-39\%} =$ Change in value of equity derivatives for a 39% fall in underlying instrument

We note that the risk factor for equity investments within the EEA and OECD is set to 0.39. This means that the loss in these equities in a 99.5 percent VaR situation is set to 39 percent.¹⁷

¹⁷ In the standard model there is a symmetric adjustment parameter added to the stress factor. The adjustment factor controls the stress factor for the level of world equity markets relative to the three-year rolling average of the MSCI World Index. The adjustment factor is within the boundary of +/- 10 percent. For simplicity reasons this factor is not present in our model.

7.2.2 Currency Risk

The 99.5 percent VaR loss for the currency position in the stress test is given by (EIOPA, 2014, p. 118):

$$L_C = -\min(0.25 * V_C + \Delta D_{C,+25\%}; -0.25 * V_C + \Delta D_{C,-25\%}) \quad \text{Equation 12}$$

L_C = Loss potential for currency position

V_C = Total net currency position

$\Delta D_{C,+25\%}$ = Change in value of currency derivatives for a 25 % immediate depreciation of NOK

$\Delta D_{C,-25\%}$ = Change in value of currency derivatives for a 25 % immediate appreciation of NOK

The total net currency position parameter means that liabilities in the same currency are subtracted. We note that the risk factor for currency is 25 percent and that the SCR model does not differentiate between different currencies.

8. Data

8.1 Data Description

Our data sample consists of time series at a daily frequency of the relevant instruments provided by Bloomberg. The instruments selection comprises stock indexes, interbank offered rates, volatility indexes, the Brent oil price, foreign exchange spot rates and forward swap points. Forward rates for EUR, USD, GBP and JPY are constructed by adding the forward swap points to the spot rates for the same period.¹⁸ The extracted data consists of closing prices of the instruments, calculated as the average between the bid and the ask quotes, and ranges from 01.01.2003 to 04.09.2015. The length of the data sample was set in search for a balance between adequate time length and relevance. Capital markets dynamics are constantly changing, making inferences from older time series less valuable for contemporary uses. Consequently, we regard 2003 to be a reasonable start date for our analysis. The lack of data on some of the forward swap points for older time series further supports this decision.

The objective for the portfolio selection applied was to replicate the international equity allocation for Norwegian life insurers while at the same time avoid unnecessary complexity. Thus, the MSCI World indexes would constitute a natural starting-point. However, by selecting only the four indexes with the highest shares in the composition, the portfolio avoids foreign exchange exposure to the remaining foreign currencies in the index. This in turn would have complicated the hedging process and modelling without adding any significant value to the analysis. The major Norwegian life insurers we have been in contact with confirm that this portfolio selection is adequately representative for the scope of this thesis (Interviews with industry professionals, Personal Communication, 2015).

The stock indexes selected are EURO STOXX-50, S&P-500, FTSE-100 and NIKKEI-100. This selection represents large cap stocks in the Eurozone, the United States, the United Kingdom and Japan respectively. The resulting foreign exchange exposure is to the euro (EUR), the U.S. dollar (USD), the pound sterling (GBP) and the yen (JPY), for which spot and

¹⁸ Because swap points extracted from Bloomberg are quoted in pips, the computations are as follows: $Forward\ rate_t = Spot\ rate_t + Forward\ swap\ points_t/10000$

forward instruments were extracted. The index values are value-weighted and adjusted for capital gains and dividends.

Finally, we extracted data on the oil price (Brent), the volatility index VIX and interbank-bank offered rates for the currency regression presented in section 10.1.2.

8.2 Descriptive Statistics of the Data

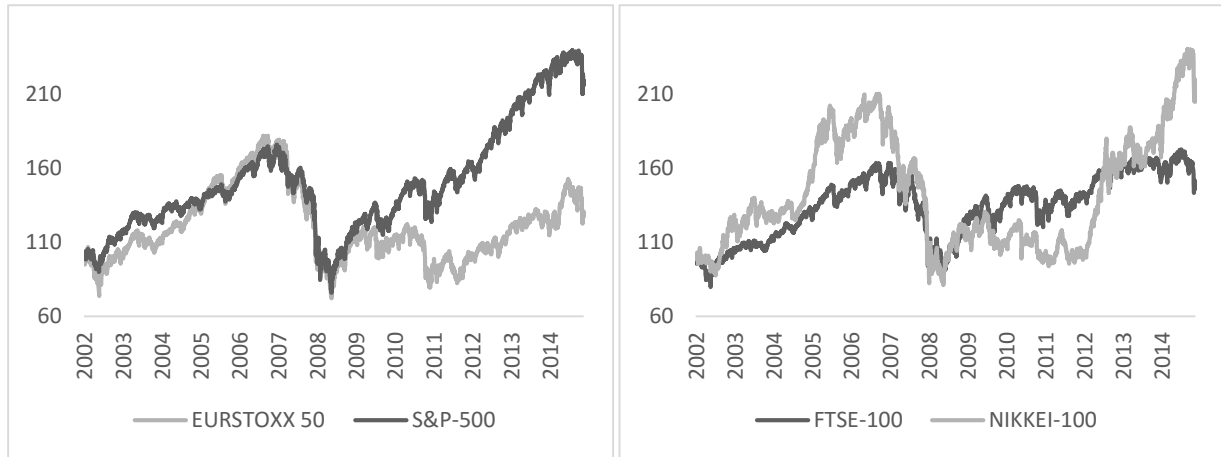


Figure 5 Indexed returns of stock indexes 2003-2015

	EURSTOXX 50	S&P-500	FTSE-100	NIKKEI-100
Return	2.28%	6.33%	3.42%	5.90%
Standard deviation	22.87%	19.30%	18.62%	23.67%

Table 1 Return and standard deviation for the stock indexes

Figure 5 and Table 1 show the development in the different stock markets during our data period. The American and Japanese stocks have delivered significantly stronger returns than the British and European ones in the period. All indexes declined during the GFC, but only NIKKEI-100 and S&P-500 have delivered decent returns since then. Whereas the Japanese and American stocks have rallied fueled by expansive monetary policies, the European debt crisis has staggered the stocks in the Eurozone and in the UK.

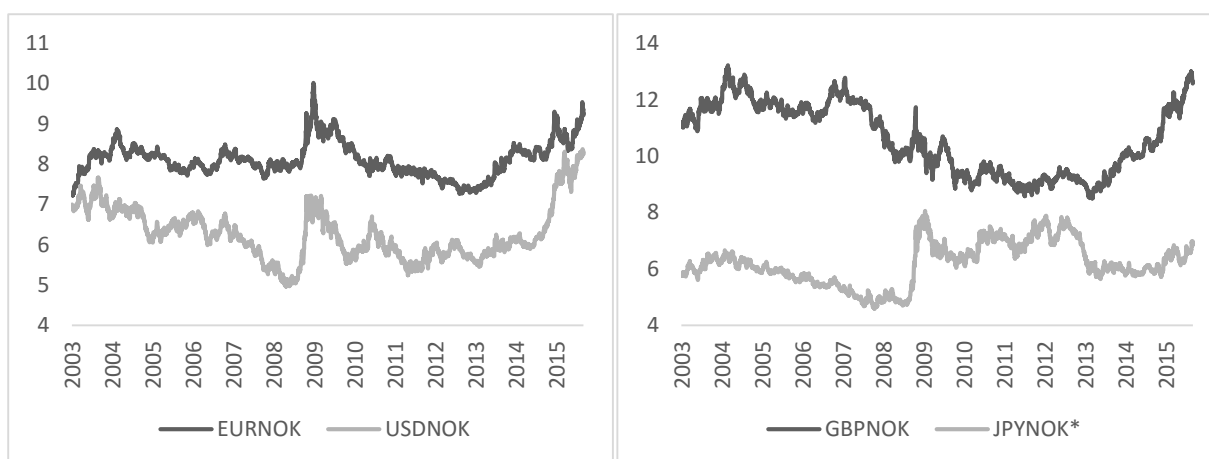


Figure 6 Foreign exchange spot rates

	EURNOK	USDNOK	GBPNOK	JPYNOK*
Return	1.90%	1.43%	0.93%	1.40%
Standard	0.42	0.66	1.25	0.75
Mean	8.11	6.27	10.62	6.19
Min	7.22	4.96	8.51	4.59
Max	10.02	8.38	13.23	8.06

*The JPYNOK is expressed as the quoted 100JPY/NOK

Table 2 Descriptive statistics for exchange rates in the years 2003-2015.

Figure 6 shows the development of the foreign exchange spot rates in our dataset. The biggest movements are seen during the GFC and in 2014 following the sharp drop in the price of oil, one of the most important variables in the Norwegian economy. Furthermore, we see that the GBP and EUR did not appreciate as much as the USD and JPY against the NOK during the GFC.

8.3 Data Issues

Bloomberg is considered one of the best databases for gathering financial data. However, we have detected some issues in our data sample. The bid and ask quotes for the 6 month forward swap points sometimes yield a negative spread for the forward rates, creating distortions in the closing data. One possible reason for this is that the quotes are often given by different providers. The problem is most severe for the GBPNOK, where roughly 2 percent of the observations yield negative bid-ask spreads. More importantly, the size of the negative spread is sometimes substantial and up to 16 basis points compared to the average of 0.5 when it is

positive. Looking into the data reveals that sudden jumps in the bid price are the source of the issue. We have thus replaced these abnormal bid prices with the corresponding ask minus the median spread over our time period. For the other currencies, the magnitude is negligible. For more details, see Appendix 13.1.

Next, in our data sample, observations from non-trading days are omitted in order to avoid distortion of statistical measures. For the same reason, missing data has been replaced by values from the preceding day.

9. Methodology

9.1 An Overview of the Model

In order to assess our key issues posed in section 4.2, we have built a back-testing model in Microsoft Excel. The first step in the model was to construct a hedged and an unhedged portfolio for the sample period and compare performances. The portfolios were computed on a daily basis throughout the back-testing period. The second step was to conduct correlation and regression analyses on the NOK in order to explain the differences in portfolio performance. The final step was to create an SCR portfolio based on the portfolio's exposure to currency risk and assess its dependency on the hedge ratio and, in particular, the input correlation parameter.

The hedging strategy implemented in the model is based on non-overlapping forward contracts with 6 months maturity.¹⁹ This means that the forward contracts are signed the first trading day of a quarter. 6 months after, on the first trading day after the two subsequent quarters, a new set of forward contracts is signed. The settlement occurs one day before the signing of new forward contracts. The hedged volume for each stock index investment, i.e. the value of the forward contracts, is given by the hedge ratio multiplied with the NOK value of the portfolio at the starting point of the hedging period:

$$\text{Hedged Volume}_{i,t} = h_i * P_{i,t^*} \quad \text{Equation 13}$$

h = hedge ratio

P = stock index investment denoted in NOK

t = starting point of the current hedging period*

We use the same hedge ratios for all four foreign currencies, which is a fair assumption based on the Norwegian life insurers' practices (Interviews with industry professionals, Personal Communication, 2015).

In order to adjust for distortion in portfolio weights (between stock indexes) arising from currency effects, we have implemented a semiannual portfolio rebalancing. Every six months, the rebalancing adjusts the portfolio weights of the hedged portfolio to coincide with those of

¹⁹ We have also tested 3 months maturity for the forward contracts in our model. The difference in results is negligible.

the unhedged portfolio if the deviation crosses a certain boundary. A small boundary would lead to the rebalancing occurring very often, whereas a large boundary would potentially create significant distortions. A boundary of 20 percent of the weight has been set as an attempt to balance between the two.²⁰ The rebalancing enables us to better isolate the hedging effects when comparing the hedged with the unhedged portfolio.

For a comprehensive overview of the variables in the model, see Appendix section 13.2. In the next three sections, we will go through how we constructed the various components.

9.2 Constructing the Portfolio

To differentiate between a hedged and an unhedged portfolio, we simply let the hedging ratio be a dynamic variable of the portfolio. When the hedge ratio is set greater than zero, the NOK rate of return will have two kinds of FX returns. One will be the return of the unhedged volume and the other one will be the return of the hedged volume. As mentioned, we have implemented a hedging strategy where the hedging volume is given by the NOK value of the stock index at the starting point of the hedging period. If the hedge ratio is not 100 percent, the unhedged volume will make up the remainder of this stock plus accumulated returns. The returns on the portfolio are in other words not hedged within the given hedging period.

Formally, the FX return on the unhedged portion of the portfolio, whose variable is named $FXRet^u$, is given by:

$$FXRet_{i,t}^u = \left[\left((1 - h_i) * P_{i,t^*} + \overbrace{\sum_{t=t^*}^T (EqRet_{i,t} + FXRet_{i,t}^u + CrossRet_{i,t})}^{\text{accumulated returns}} \right) \right] * e_{i,t} \quad \text{Equation 14}$$

e = currency return

Next, the FX return on the hedged volume, whose variable is named $FXRet^h$, is given by:

$$FXRet_{i,t}^h = h_i * P_{i,t^*} * f_{i,t}^* \quad \text{Equation 15}$$

²⁰ A sensitivity analysis show that the results in our analysis are not very sensitive to the rebalancing boundary. Changing the rebalancing boundary from 0 to 40 percent changes return and volatility measures in the hedged portfolio in the range from 0 to 0.15 percent. See Appendix 13.4 for details.

$$f_{i,t}^* = (f_{i,t^*}/s_{i,t^*} - 1) - Spread_i \quad \text{Equation 16}$$

The variable f^* is the forward premium or discount computed as the forward rate over the spot rate at the time of the forward contracts signing, i.e. $t=t^*$. The variable is also adjusted for a bid-ask spread which represents the direct cost of hedging.²¹ The FX return on the hedged volume will only be realized when the forward contracts are settled, i.e. $t=t^*-1$.

In total, the stock index investment in NOK at time t for index i will be given by:

$$P_{i,t} = \begin{cases} P_{i,t-1} + EqRet_{i,t} + FXRet_{i,t}^u + FXRet_{i,t}^h + CrossRet_{i,t}, & t = t^* - 1 \\ P_{i,t-1} + EqRet_{i,t} + FXRet_{i,t}^u + CrossRet_{i,t}, & \text{Otherwise} \end{cases} \quad \text{Equation 17}$$

The realization of the forward contracts is implemented in the model by adding the FX return from hedging activity at time $t=t^*-1$. Equation 17 shows that equity returns, FX returns on the unhedged volume, and cross returns are compounded on a daily basis. FX returns on the hedged volume, on the other hand, are compounded on a semiannual basis (as the hedging periods are semiannual). Note that we have excluded the portfolio rebalancing component from Equation 17 for the sake of transparency for the reader. For a complete description, see Appendix 13.2.7).

The overall equity portfolio in NOK will be the sum of the four different stock index investments:

$$Portfolio_t = \sum_{i=1}^4 P_{i,t} \quad \text{Equation 18}$$

9.3 Constructing the SCR Portfolio

The SCR portfolio is the portfolio consisting of capital set aside due to compliance with SCR from currency exposure. In order to isolate these requirements, we only implement the SCR from the potential loss from currency risk, adjusted for diversification. Even though we are only assessing currency risk in this thesis, in order to get a precise estimate of the specific capital requirement, one would need to quantify all risk modules to fully account for the diversification effects. This exercise would require extensive firm-specific information in

²¹ For details on the calculation of the average spread, see Appendix 13.1

addition to a very demanding model. A natural approach is to solely account for the diversification derived from correlation between currency and equity markets as both elements are fundamental to our model. The diversification from correlation with the other risk modules will reduce the size of the SCR portfolio, but will not influence the assessment of the equity-currency correlation input parameter.

The SCR from currency risk, denoted SCR^C , at each point in time will be given by the stand-alone potential losses from currency exposure, minus the diversification effect:

$$SCR_t^C = L_{C,t} - Diversification_t \quad \text{Equation 19}$$

The diversification effect is computed by taking the difference between the sum of stand-alone potential losses from equity and currency exposure and the total loss potential adjusted diversification.

Total loss potential adjusted for diversification L_t is given by the square root of the matrix multiplication:

$$L_t = \sqrt{\begin{bmatrix} L_{E,t} & L_{C,t} \end{bmatrix} \begin{bmatrix} 1 & 0.25 \\ 0.25 & 1 \end{bmatrix} \begin{bmatrix} L_{E,t} \\ L_{C,t} \end{bmatrix}} \quad \text{Equation 20}$$

Or:

$$L_t = L_{E,t} + L_{C,t} - Diversification_t \quad \text{Equation 21}$$

By rearranging we get the diversification effect from Equation 19:

$$Diversification_t = L_{E,t} + L_{C,t} - L_t \quad \text{Equation 22}$$

The potential losses from equity and currency exposure, L_E and L_C respectively, are found by multiplying the exposure with the appropriate stress factor as shown in section 7.2. The correlation matrix in Equation 20 is a simplified version of the correlation matrix $Corr$ in Equation 10.

The equity exposure, or value of the equity positions, is simply the current equity portfolio value. The value of the currency positions, on the other hand, is less straight-forward as hedging activity needs to be taken into account. The value of the currency positions, denoted V_C , is given by the current portfolio subtracted the hedging volume and accumulated returns, shown by the following formula:

$$V_{C,t} = \max\left[P_{i,t} - \sum_{i=1}^4 (h_i * P_{i,t}^*), 0\right]$$

Equation 23

The max function is used to avoid negative values. A negative currency exposure might arise during a period of negative equity returns combined with a high hedge ratio.

10. Results and Analysis

To try to answer if the treatment of currency risk in Solvency II is reasonable for the Norwegian market, we will begin by comparing the results and selected performance measures for a fully hedged portfolio (100 percent hedge ratio) with those for an unhedged portfolio (0 percent hedge ratio). In section 10.1.1 we seek to explain the deviations in performance between the two portfolios by conducting a correlation analysis between currency and equity markets. These dynamics are further explored in section 10.1.2 where we take a closer look at the characteristics of the NOK by performing regression analyses.

The second part of this section incorporates an analysis of the SCR from currency risk and how this might affect currency risk management among Norwegian life insurers.

10.1 Analysis of Hedging Currency Risk with NOK as a Base Currency

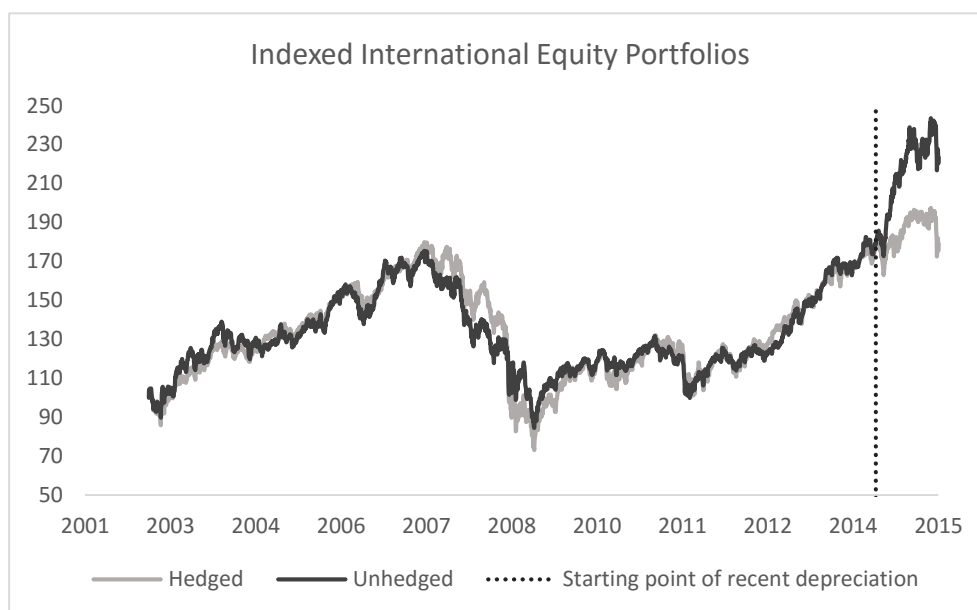


Figure 7 Indexed hedged and unhedged international equity portfolios denoted in NOK

	Whole sample period			Excluding recent depreciation		
	Unhedged	Hedged	Diff	Unhedged	Hedged	Diff
Average Return	6.39%	4.52%	1.87%	5.27%	5.04%	0.22%
Volatility	16.64%	18.05%	-1.41%	16.68%	18.43%	-1.74%
Downside vol	11.63%	14.54%	-2.90%	11.67%	13.33%	-1.66%

Table 2 Portfolio performance for the entire sample period and the period before the recent depreciation

In Figure 7 we see that the indexed returns of the hedged portfolio and the unhedged portfolio have followed each other quite closely throughout the sample period. The exception is the last year where we see a significant divergence. Furthermore, the hedged portfolio generally shows higher tops and lower bottoms. This picture is reflected in Table 2 showing that from 2003 to 2015 the unhedged portfolio outperforms the fully hedged portfolio for all our selected performance measures. Most importantly, the downside volatility (semideviation), which we have seen is what life insurers are mostly concerned about, is considerably higher for a fully hedged portfolio. In other words, a Norwegian life insurer that has fully hedged its currency positions consistently over the last 13 years has performed worse than sitting passively in an open position. Table 2 also illustrates that these observations also holds when we exclude the recent depreciation of the NOK.

We will now take a closer look at the performance measures for each hedging period separately.

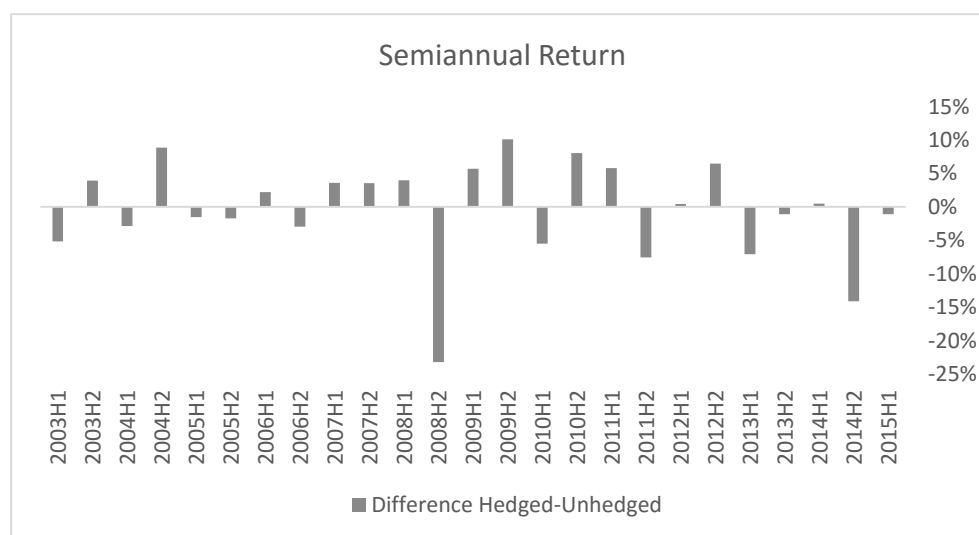


Figure 8 Difference in semiannual return between the hedged and unhedged portfolio

When considering the rate of return, we can see from Figure 8 that the fully hedged portfolio outperformed its unhedged counterpart in 13 out of 25 semiannual periods. However, the geometric average for the whole period seen in Table 2 is notably inferior. This is largely due to the recent depreciation of the NOK. The differences in the rate of return between the two portfolios are caused by future spot rates deviating from the forward rates, shown in Figure 9. By comparing Figure 8 and Figure 9 we see that the differences in return are greatest in times where the gap between the future spot rate and the forward rate is significant. For example, we see that during the GFC, the spot rate far exceeded the forward rate (set 6 months earlier),

as the NOK plummeted against all four currencies. A hedged Norwegian insurer with international assets would in this case missed a significant currency return.

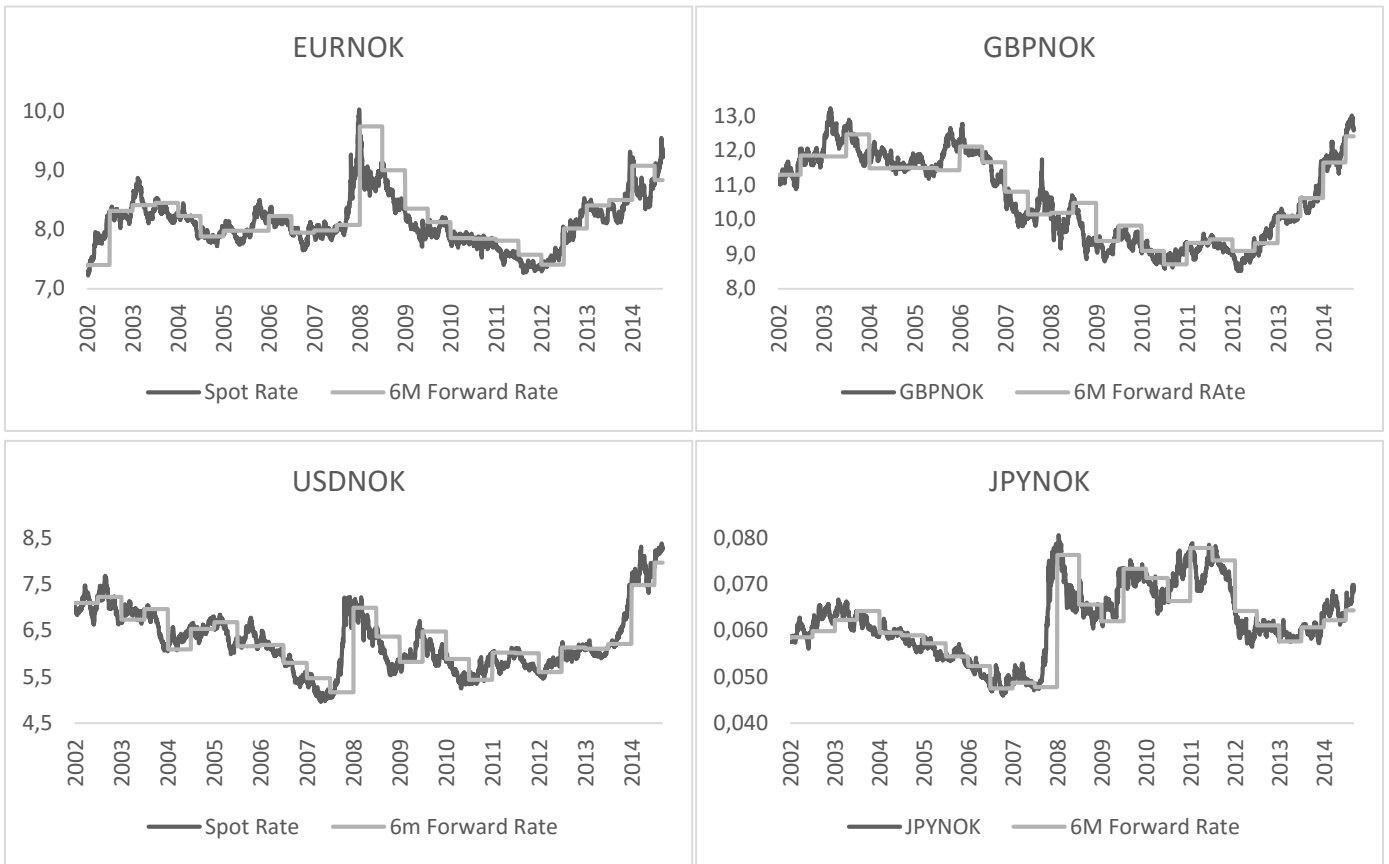


Figure 9 Forward rates and actual spot rates

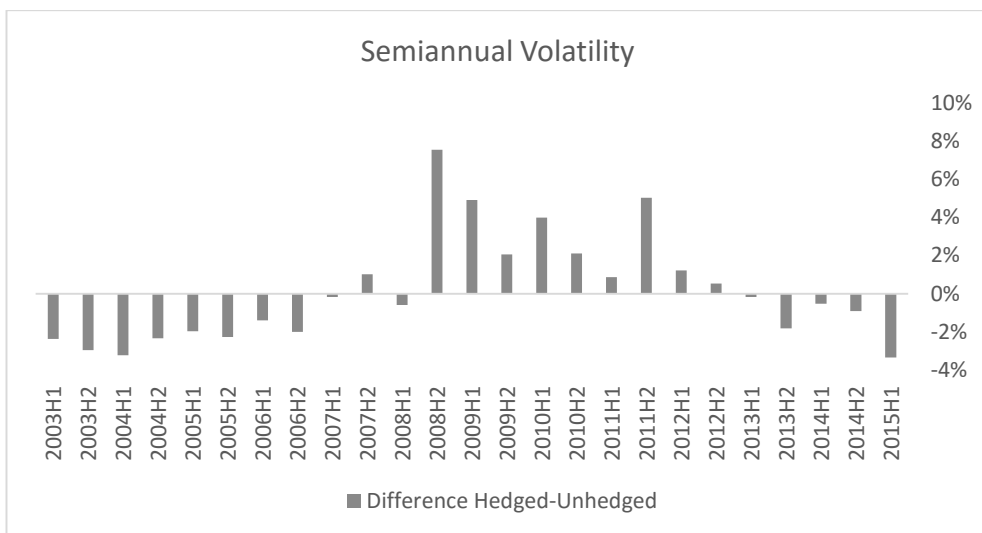


Figure 10 Difference in semiannual volatility between the hedged and unhedged portfolio

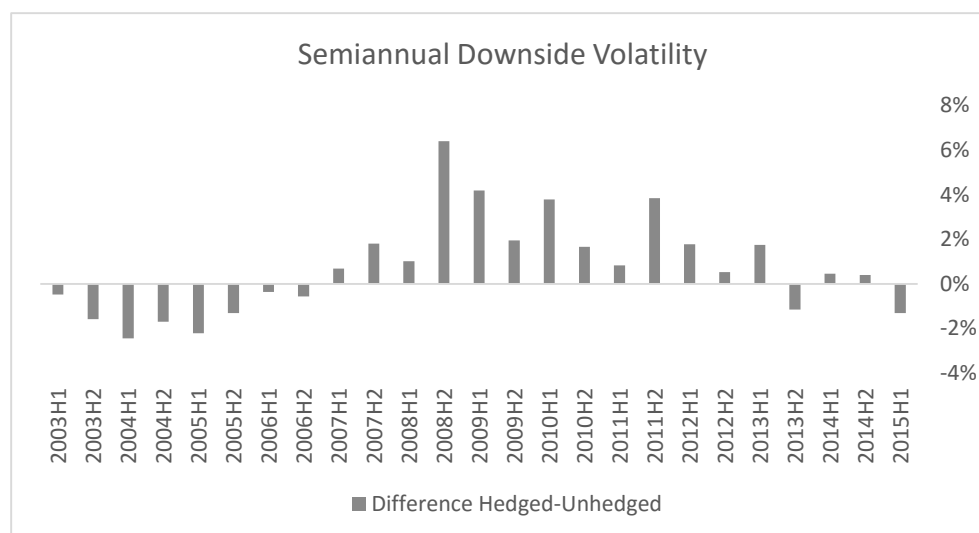


Figure 11 Difference in semiannual downside volatility between the hedged and unhedged portfolio

Figure 10 and Figure 11 illustrate the semiannual volatility and downside volatility respectively. Note that a positive difference here means that the (downside) volatility is higher, i.e. reflecting an inferior performance of the hedged portfolio. For the semiannual volatility, we make two observations. The hedged portfolio outperforms the unhedged one in number of periods, but when the unhedged portfolio is superior, the magnitude is bigger. For the downside volatility, measured by the semideviation with a threshold of zero, we see a much clearer picture in terms of which portfolio is superior. The unhedged portfolio far outperforms the hedged one both in number of periods and magnitude.

We have seen that hedging currency risk has worked against its purpose of reducing risk in our sample period by in fact increasing volatility. Even though the GFC has a major saying in this, handling extreme market downturns is what the SCR is designed for, making the GFC highly relevant for this assessment. What matters more is that downside volatility increases significantly when hedging the equity portfolio. In order to understand this phenomenon, we need to look into the correlation between the NOK and international equity markets.

10.1.1 Correlation Analysis

Previous research has emphasized the importance of the equity-currency correlation for the hedging decision (LaBarge, Thomas, Polanco, & Schlanger, 2014). The sign and strength of the correlation between currency and equity returns will have an impact on the outcome of the hedging strategy. Thus, grasping the equity-currency dynamics is an essential prerequisite for understanding the impact of hedging. Some empirical research on this topic has been

conducted, but the majority of the papers concentrate on bigger currencies with different properties than the NOK such as the USD and EUR.²²

When investing in foreign equity, one implicitly invests in two separate assets; foreign equity and foreign currency. In order to assess the dynamics of this portfolio, a single index framework is commonly used.²³

In this framework, the portfolio volatility is computed according to Markowitz' (1952) well-known two-asset portfolio model, where the equity is one asset and the respective foreign currency is the other. Portfolio volatility for portfolio q consisting of equity index i and currency pair j , $\sigma_{p,q}$, is according to Markowitz' model given by:

$$\sqrt{\sigma_{p,q}^2 = \sigma_{e,i}^2 + w_{c,j}^2 * \sigma_{c,j}^2 + 2 * w_{c,j} * \sigma_{e,i} * \sigma_{c,j} * \rho_{e,c}} \quad \text{Equation 24}$$

$\sigma_{e,i}$ = standard deviation of equity index i

$\sigma_{c,j}$ = standard deviation of currency pair j

$w_{c,j}$ = weight allocated in the foreign currency j (100% corresponding to an open position and 0% to a fully hedged position)

$\rho_{e,c}$ = correlation coefficient for the correlation between equity and currency returns

The portfolio variance-minimizing currency exposure is given by:

$$w_{c,j}^* = - \frac{\rho_{e,c} / \sigma_{c,j}}{\sigma_{e,i}} \quad \text{Equation 25}$$

From Equation 25 we see that the optimal exposure to currency is dependent on both the equity-currency correlation and the relative volatility between these two assets. If there is significant negative correlation, having the currency as an asset in your portfolio will decrease the overall volatility. Consequently, we see from Equation 25 that if the correlation falls below 0, the optimal allocation to currency rises, i.e. the hedge ratio falls. The size of the relative volatility $\sigma_{c,i}/\sigma_{e,j}$ will have an effect on the impact the correlation has on the optimal hedge ratio. The greater the relative volatility, the less important correlation is for the hedge ratio. For example, for international fixed income securities, the volatility in the currency returns

²² For further studies on the dynamics of the relationship between currency and equity see (Boudoukh, Katz, Richardson, & Tapar, 2015), (Phylaktis & Ravalozzo, 2005) and/or (Cumperayot, Keijzer, & Kouwenberg, 2006)

²³ See Labarge et al (2014) for a similar analysis on different currency and equity indexes.

will often be greater than that of fixed income securities. Hence, in an unhedged portfolio of foreign fixed income, most of the portfolio volatility will originate from the currency volatility. As a result, firms often fully hedge positions in fixed income. For equities, the optimal currency exposure is more complex. The single index framework serves as one of the tools for understanding how the relationship between the NOK and foreign equity affects the hedging decision.²⁴

For the inputs in the two-asset model we have used the annualized standard deviation in the daily equity and currency returns for the various indexes in our sample period.²⁵ Table 3 shows the optimal hedge ratio for different equity-currency correlations. The key takeaway from this table is that correlation matters a lot for the optimal hedge ratio for international equity portfolios. We see that for any correlations below 0, the optimal policy is to have at least some exposure to currency. The correlation threshold from where it is best not to hedge at all (hedge ratio of 0 percent) is shown in Table 4. For significantly low correlations it is best to acquire currency exposure in excess of the equity investment. In scenarios with high positive correlation the optimal strategy is to over-hedge (i.e. short the foreign currency). However, hedge ratios outside of the 0-100 percent bound are rarely observed in practice.

²⁴It is important to note that the single index framework is in fact a single index framework. The diversification benefits across the different indexes and currencies that you will get in a composite portfolio is not found in this model. The single index framework is nevertheless a great tool for understanding the dynamics between volatility and correlation.

²⁵ The interest rate differential return is not included in our measure of currency return. Furthermore, it is well established that ex-post volatility does not equal the future volatility and one should keep this in mind while interpreting the analysis.

Correlation	Optimal Hedge Ratio			
	USA	EURO	GB	JP
-1	-49%	-185%	-78%	-53%
-0.8	-19%	-128%	-42%	-23%
-0.6	11%	-71%	-7%	8%
-0.4	40%	-14%	29%	39%
-0.2	70%	43%	64%	69%
0	100%	100%	100%	100%
0.2	130%	157%	136%	131%
0.4	160%	214%	171%	161%
0.6	189%	271%	207%	192%
0.8	219%	328%	242%	223%
1	249%	385%	278%	253%

Table 3 Optimal hedge ratio calculated as the $1 - w_{c,j}^*$ (the optimal currency exposure) from Equation 25 for different correlation parameters

	US	EZ	GB	JP
Currency volatility σ_c	12.95%	8.03%	10.46%	15.44%
Equity volatility σ_e	19.30%	22.87%	18.62%	23.67%
Relative volatility σ_c/σ_e	0.67	0.35	0.56	0.65
Correlation from where optimal hedge ratio = 0 %	-0.34	-0.18	-0.28	-0.33

Table 4 Properties of the foreign equity indexes and foreign currency against the NOK

Table 4 shows that EURNOK has the lowest relative volatility while the USDNOK has the highest. A Norwegian life insurer investing in equity in the Eurozone would minimize portfolio volatility by imposing a hedge ratio of zero if the correlation between stocks and currency is -0.18 or below, whereas the threshold is -0.34 for American equities.

It is evident that addressing the correlation and relative volatility between the NOK and foreign equity is important before laying out a hedging strategy. Furthermore, it should be in the industry and regulators' interest to assess whether the parameters in the standard model for the SCR computation are representative for the Norwegian market. Next, we will in light of the observations made above, assess the historical equity-currency correlations and evaluate their implications for hedging strategies for Norwegian life insurers.

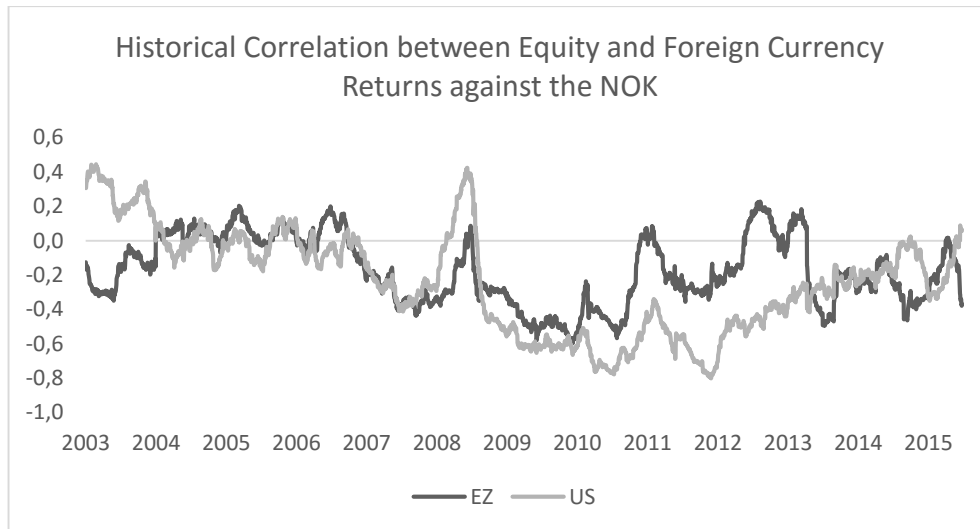


Figure 12 100-day rolling equity-currency correlation factor for the Eurozone and the US

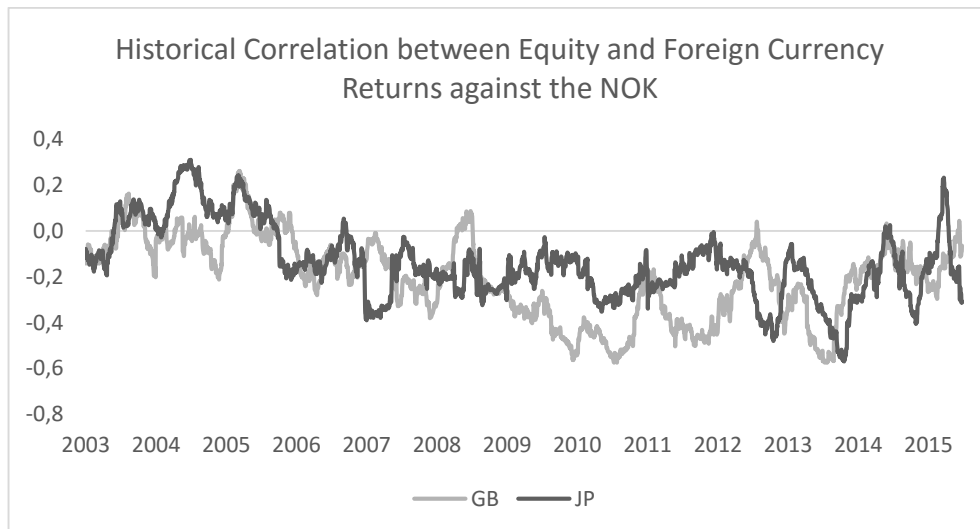


Figure 13 100-day rolling equity-currency correlation factor for the UK and Japan

Figure 12 and Figure 13 illustrate the 100-day rolling linear correlation between the return of the NOK and stock markets in the sample period. Note that the 100-day rolling correlation creates a significant lag in the figures. For example, as the stock markets started collapsing after the bankruptcy of Lehman Brothers in September 2008, the resulting correlations are not completely embedded in the figures until the spring of 2009. At that point we observe very low correlations. A trend in both charts above is that the correlation factors for most of the period fluctuate below zero. In fact, the correlation is positive only roughly one fifth of the

time during our sample period.²⁶ In other words, our data indicates that the value of the currency positions and equity positions mostly move in opposite directions. Consequently, it may seem that exposure to currency for Norwegian life insurers add diversification benefits to the foreign equity positions, potentially explaining the lower volatility of the unhedged portfolio.

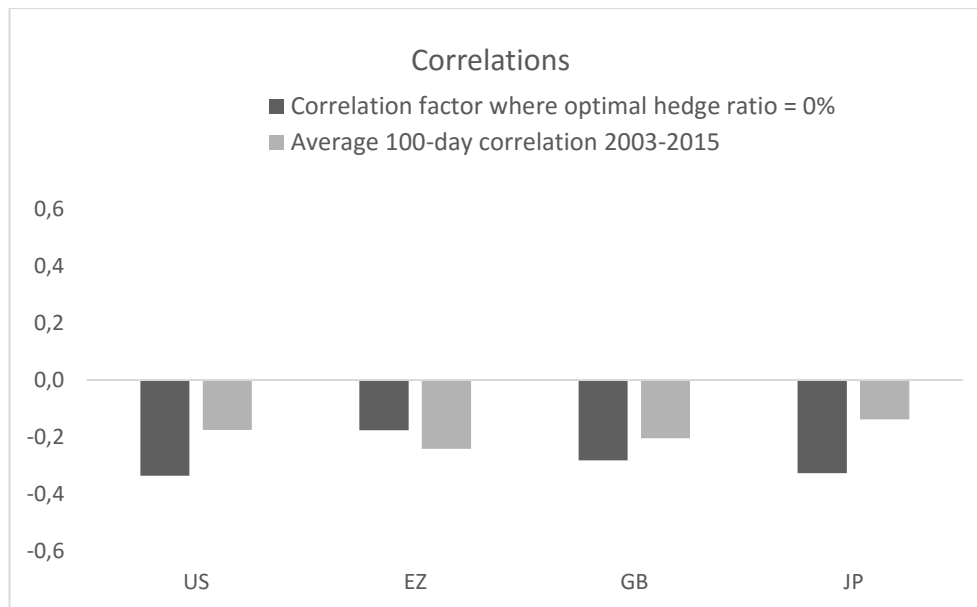


Figure 14 Average historical correlation vs correlation from where optimal hedge ratio = 0%

Figure 14 shows that in our sample period, for all currencies but the euro, the optimal hedge ratio has been above 0 percent but less than 100 percent. For the euro, on average, it has been optimal not to hedge the currency position at all according to the single index framework.

In order to understand the mostly negative correlation between the currency and equity returns for a Norwegian investor, we will now take a closer look at the characteristics of the NOK.

10.1.2 The Norwegian Krone

The national currency of Norway, the Norwegian Krone (NOK), is the 14th most traded currency in the world (Bank for International Settlements, 2013).²⁷ It is generally considered

²⁶ Calculated as the weighted average of the rolling 100 day historic correlation below 0. Exact number is 22 percent.

²⁷ Based on the OTC foreign exchange turnover in April 2013, adjusted for local and cross-border inter-dealer double-counting (net-net basis).

to be a relatively illiquid currency and highly linked to the oil price. The central bank of Norway (Norges Bank) operates with a free-floating currency regime.

In a research article from 2000, Norges Bank assesses the short- and long-term drivers of the NOK. In the long-term, they find that the oil price and the price level differential between the foreign country and Norway drive the exchange rate. In the short-term, they find that also international financial turbulence and the interest rate differential affect the exchange rate. (Bernhardsen & Røisland, 2000)

For the purpose of explaining the results found in the model, we have conducted a simple regression analysis for the main drivers of the NOK; the interest rate differential, the oil price (Brent) and the volatility index (VIX).²⁸ The interest rate differential is computed as the Norwegian interest rate subtracted the foreign interest rate.²⁹ As we can see from Figure 15, market turmoil, represented by the VIX, was especially high during the two years of the GFC in 2008-2009. Hence, a natural approach is to separate the periods divided by the GFC when conducting the regressions in order to capture the dynamics during different market conditions. The mechanisms influencing the variables included in the regressions are highly complex, and even though these variables are known to be stationary processes, the regressions might be prone to endogeneity.³⁰ Hence, one should be careful when interpreting the regression results and in particular the value of the coefficients. Rather than defining true causal effects, our analysis is intended to give the reader a general picture of the drivers of the NOK.

We have printed the regression output for the USDNOK rate in Table 5, as the weight in the USD is dominant in the international equity allocation in our model. The regression outputs for the other exchange rates can be found in Appendix 13.2.9. The USDNOK regressions suggest a positive relationship between NOK and the two drivers; oil price and interest rate spread. This means that the isolated effect of an increase in either of the drivers will on average lead to an appreciation of the NOK against the USD. This is in line with the perceptions about the NOK. First, the oil price is probably the most important single parameter for the Norwegian

²⁸ The CBOE Volatility Index (VIX) is made up of implied volatility rates conveyed by S&P-500 stock index option prices. It is regarded as one of the premier barometers for investor sentiment and market volatility (CBOE, u.d.)

²⁹ As proxies for interest rates, we have used the 3 months interbank offered rates.

³⁰ Endogeneity arises when your model for some reason do not reflect the true relationship between your variables.

economy and a change in this price will affect dollar-based investors' demand for the NOK. Second, a higher interest rate in Norway means a greater return in the fixed income market, attracting foreign investors.

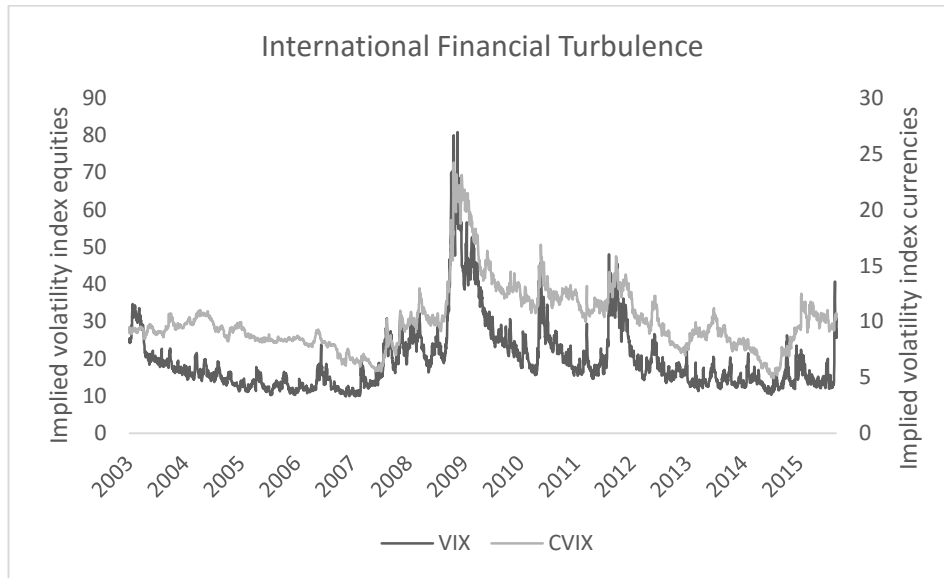


Figure 15 Turbulence measured by the indexes for implied volatility in equities (VIX) and currencies (CVIX)

Dependent variable: USDNOK 2003-2007					Dependent variable: USDNOK 2010-2015				
	IR	Oil	VIX	Const		IR	Oil	VIX	Const
Coeff	-0.095**	-0.028**	0.017**	7.65**	Coeff	-0.67**	-0.023**	0.009**	9.46**
r ²	75.15%				r ²	84.60%			
Dependent variable: USDNOK 2008-2009 (GFC)									
	IR	Oil	VIX	Const					
Coeff	0.022	-0.018**	0.017**	6.783**					
r ²	90.83%								

* p-value of coefficient is less than 0.10, ** p-value of coefficient is less than 0.05

Table 5 - Regression with USDNOK as dependent variable and interest rate spread, oil price and CVIX as independent variables

Next, our regressions exhibit a negative relationship between the USDNOK and the VIX. In times of high volatility the NOK seems to depreciate against the dollar. This relationship reflects the risk perception of NOK in the market. During a risk-on period³¹, investors build

³¹ A risk-on period means a period where investors are more willing to take on risk.

up their positions in NOK in search for higher returns³², whereas during a risk-off period, they tend to fly to safe-haven currencies. This phenomenon is also found for EURNOK, GBPNOK and JPYNOK. The exception is GBPNOK in the period 2003-2007, and EURNOK in the period 2010-2015. The latter can be explained by the Eurozone debt crisis that occurred within that period decreasing investors' trust in the EUR.

The correlation between international equity markets and the NOK, discussed in section 10.1.1, might be partly explained by the NOK's relationship with market volatility. The magnitude of this negative relationship is dependent on the size of the positions in NOK investors build up during a risk-on period, which again is dependent on the yield differential in fixed income. Obviously, noise from other factors such as the oil price will distort the correlation.

The bottom line for these analyses is that the equity-currency correlation for an investor with NOK as a base currency has mostly been negative, which in turn has been caused by the historical risk-on characteristics of the NOK. This explains why hedging has caused higher levels of volatility than not hedging in this period. With this in mind, we will now discuss its relevance in the context of SCR.

³² The Norwegian interest rates have generally been higher than the other 4 in our sample period.

10.2 Analysis of the Solvency Capital Requirement from Currency Risk

We remember from section 7.1 that Norwegian life insurers under Solvency II must hold capital to withstand losses from their exposure to, among other things, currency risk. The correlation set between the risk modules in the computation of SCR matters because it affects the diversification effect. The lower the correlation input parameter, the higher the diversification effect, yielding lower capital adequacy requirements. In the previous section, we found that the equity-currency correlation for an investor with NOK as base currency mostly has been negative. In the standard model elaborated by the European Commission, adapted directly by Norwegian regulatory authorities, this correlation parameter is set to 0.25. In this section we will discuss how the SCR from currency risk depends on the hedge ratio and, in particular, the impact of the correlation parameter.

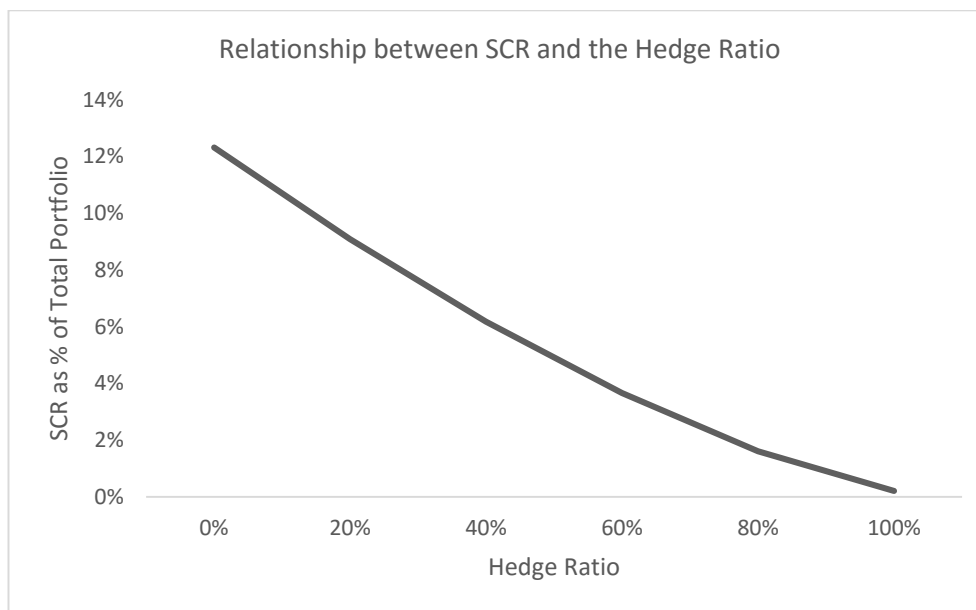


Figure 16 Relationship between SCR from currency risk and the hedge ratio.

Figure 16 shows the relationship between the share of SCR over the equity portfolio and the hedge ratio. Note that the size of these SCR portfolios are higher than in a real context due to ignored diversification effect from other risk modules (see section 9.3). However, the inferences from the analysis still hold as the mechanisms for the SCR are the same. The clear picture here is that the SCR falls with the level of hedging. Setting capital aside for buffer purposes is costly for any business. Equity and debt issues are costly, and the opportunity cost of deploying capital in the assets qualified as “own funds” (described in section 7.1)

might be significant. Next, we analyze how sensitive the SCR is with respect to the equity-currency correlation parameter in the standard model for various hedge ratios.

Equity-Currency Correlation	Hedge Ratio				
	0%	25%	50%	75%	100%
-0.30	0,51 %	0,00 %	0,00 %	0,00 %	0,00 %
-0.20	2,90 %	0,76 %	0,00 %	0,00 %	0,00 %
-0.10	5,17 %	2,56 %	0,77 %	0,01 %	0,00 %
0.00	7,32 %	4,29 %	1,98 %	0,54 %	0,02 %
0.10	9,38 %	5,95 %	3,16 %	1,16 %	0,10 %
0.20	11,36 %	7,55 %	4,31 %	1,77 %	0,17 %
0.25	12,32 %	8,33 %	4,87 %	2,07 %	0,21 %
0.30	13,26 %	9,10 %	5,42 %	2,37 %	0,25 %
0.40	15,09 %	10,60 %	6,51 %	2,96 %	0,33 %
0.50	16,87 %	12,05 %	7,57 %	3,54 %	0,40 %

Table 6 SCR as percentage of total portfolio for different hedge ratios and correlation parameters

Table 6 shows the output for this sensitivity analysis. The correlation parameter from the standard formula is highlighted in the table. The output clearly shows that the correlation parameter has a noteworthy effect on the SCR; in other words, the diversification effect is significant. An interesting observation is that for 0 percent hedge ratio, an adjustment of the input correlation parameter to 0 would reduce the share of SCR by 41 percent.³³ There are several key takeaways from the sensitivity analysis. First, the magnitude of the diversification effect is inverse-proportional to the hedge ratio; the higher the hedge ratio, the lower the diversification. When operating with high hedging ratios, the SCR from currency risk is so small that the diversification effect is almost negligible. Second, the impact of changing the hedge ratio has a smaller effect for lower input correlation parameters. Decreasing the hedging activity will hence have less of an impact, in terms of increased capital adequacy requirements, when the input correlation parameter is low.

All in all, the analysis above suggests that the current input correlation parameter in the standard formula incentivizes insurers not to open up for less hedging activity (moving from right to left in Table 6) in their risk management policies. Capital employed in the “own funds” tiers will yield returns close to the current money market rates, which is much lower than the

³³ Calculated based on the SCR shares shown in Table 6. $(12.32\% - 7.32\%) / 12.32\% = 41\%$

cost of capital. Increased SCR will hence lead to a lower return on capital for the firm. EIOPA has estimated a universal annual cost of capital of 6 percent (EIOPA, 2010, p. 18). If we assume that the return on the “own funds” mostly resemble the risk-free rate, the cost for setting aside capital in accordance with Solvency II is close to 6 percent annually. This emphasizes that the capital requirements from currency risk in Solvency II come at a considerable price.

To conclude, we deem it questionable that the input correlation parameter for the equity-currency risk in the standard formula from EIOPA is reasonable for the Norwegian market. There could be potentially significant cost savings from implementing more customized SCR models without sacrificing financial stability. On the contrary, one might observe more financial stability with lower capital requirements from currency risk as a result of less hedging activity among Norwegian life insurers.

11. Conclusion

We have seen that in the period from January 2003 to September 2015, a hedged equity portfolio has underperformed its unhedged counterpart with respect to the rate of return, volatility and, in particular, downside volatility. The last-mentioned performance measure is what Norwegian life insurers predominantly focus on for their group portfolio, because they bear all the risk of not meeting the annual guaranteed rates of their defined benefit products. The difference in performance on volatility between a hedged and an unhedged portfolio is caused by the equity-currency correlation, which for the NOK has mostly been negative throughout the sample period. Furthermore, we have seen that correlation is significantly negative in what clearly is the most turbulent period in our sample period, namely the GFC. This negative correlation can be explained by the risk-on characteristics of the NOK, meaning that the currency is negatively correlated with the risk perception in financial markets.

The standard model for SCR adopted by the regulatory authorities in Norway sets the input parameter for the 99.5 percent VaR correlation between equity and currency to 0.25. We acknowledge that this input parameter is set on a conservative basis and that the 99.5 percent VaR correlation is hardly quantifiable. However, whereas the standard model's correlation parameter might be reasonable for an investor with the euro as a base currency, we question its applicability for a Norwegian investor as it contradicts historical market dynamics.

The size of the SCR from currency exposure is highly sensitive to both the currency hedge ratio and the input equity-currency correlation parameter. A high hedge ratio, which is the current practice in the risk management of Norwegian life insurers, yields a lower SCR. A high input correlation parameter, on the other hand, increases the SCR. As the cost of capital is a lot higher than the returns on buffer capital, the higher the SCR, the lower the return on capital for the firm. Imposing a higher correlation input parameter than what might be more representative for the Norwegian market will thus limit insurers' motivation to lower their hedge ratios. A lower hedging activity would lead to less volatile portfolio returns if the dynamics of the NOK do not drastically change. The result is that the SCR from currency risk, through their incentives on risk management, might lead to less financial stability, which is the exact opposite of the main motivation of Solvency II.

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13. Appendix

13.1 Direct Cost of Hedging

The following table presents selected summary statistics of the bid-ask spreads for forward rates with a maturity of 6 months. Since we are dealing with a dataset sometimes yielding negative spreads, the median will provide a better measure than the average. Thus, we have chosen the median spread in our model. Note that the reason why the JPYNOK spread is much smaller than the rest, is that the foreign exchange rate is quoted as 100JPY/NOK.

Bid-ask spreads for 6M forwards				
	EURNOK	USDNOK	GBPNOK	JPYNOK
Median	0.0021	0.0015	0.0029	0.000018
# of negative spreads	37	15	66	14

Table 7 Selected summary statistics of the bid-ask spreads for 6M forwards

13.2 A Comprehensive Overview of the Variables in the Model

13.2.1 General Remarks

In this section, we present the variables included in the model and how they are computed.

The subscript i refers to the stock index and foreign exchange rate. Specifically, $i \in [1, 4]$ where the numbers represent the instruments as shown below.

$i=1$	<i>EUROSTOXX-50 / EURNOK</i>
$i=2$	<i>S&P-500 / USDNOK</i>
$i=3$	<i>FTSE-100 / GBPNOK</i>
$i=4$	<i>NIKKEI-100 / JPYNOK</i>

The subscript t refers to the trading days from 31.12.2002 to 04.09.2015. Specifically, $t \in [0, 3308]$ where $t=0$ is 31.12.2002 and $t=3308$ is 04.09.2015. t^* refers to the beginning of the current hedging period, technically the time of forward contracts signing.

In the following sections, all variable formulas hold for $t \in [1, 3308]$. For $t = 0$, see section 13.2.9. The format is illustrated by the following example:

Mathematical formulation of variable

Description of variable

13.2.2 Hardcoded Data

The following variables constitute the Bloomberg data pasted as hardcoded values in the model spreadsheet.

$Date_t$

Date variable

$S_{i,t}$

Foreign exchange spot rate

$f_{i,t}$

Foreign exchange forward rate

$p_{i,t}$

Stock index in local currency

13.2.3 Input Data

h_i

Hedge ratio

$Spread_i$

Average bid-ask spread of forward contracts (see Appendix 13.1)

B

Rebalancing boundary

$Capital$

Initial capital invested

13.2.4 Counter Variable

The counter variable is created for the use of the OFFSET() function in MS Excel which is used extensively in the model.

$$HedgeCounter_t = \begin{cases} 0, & D.6M = 1 \\ HedgeCounter_{t-1} + 1, & Otherwise \end{cases}$$

Counts the number of days since the starting point of the current hedging period

13.2.5 Dummy Variables

$$D.Rebalance_t = \begin{cases} 1, & w_i < (1 - B) * w_i^* \text{ or } w_i > (1 + B) * w_i^* \\ 0, & Otherwise \end{cases}$$

Dummy variable showing whether the hedged portfolio needs rebalancing

$$D.6M_t = \begin{cases} 1, & t = t^* \\ 0, & Otherwise \end{cases}$$

Dummy variable taking the value of 1 at the beginning of each semiannual period, i.e. the starting point for a new hedging period

13.2.6 Instruments Return Variables

$$f_{i,t}^* = (f_{i,t^*}/s_{i,t^*} - 1) - Spread_i$$

Forward premium/discount computed as the forward rate over the spot rate at the time of forward contract signing

$$r_{i,t} = p_{i,t}/p_{i,t-1} - 1$$

Local equity return

$$e_{i,t} = s_{i,t}/s_{i,t-1} - 1$$

Rate of appreciation of local currency against the NOK

13.2.7 Equity Portfolio Variables

$$EqRet_{i,t} = P_{i,t-1} * r_{i,t}$$

Equity return

$$FXRet_{i,t}^u = \left[\left((1 - h_i) * P_{i,t} + \sum_{t=t^*}^{t=T} (EqRet_{i,t} + FXRet_{i,t}^u + CrossRet_{i,t}) \right) \right] * e_{i,t}$$

FX return for the unhedged volume

$$FXRet_{i,t}^h = h_i * P_{i,t^*-1} * f_{i,t}^*$$

FX return for hedged volume

$$CrossRet_{i,t} = EqRet_{i,t} * e_{i,t}$$

Cross return

$$w_{i,t} = \frac{P_{i,t}}{Portfolio_t}$$

Weight of each stock index in the overall portfolio

$$P_{i,t} = \begin{cases} P_{i,t-1} + EqRet_{i,t} + FXRet_{i,t}^u + FXRet_{i,t}^h + CrossRet_{i,t}, & D.Hedge_t = 1 \text{ and } D.Rebalance_t = 0 \\ Portfolio_{t-1} * w_{i,t-1}^u + EqRet_{i,t} + FXRet_{i,t}^u + FXRet_{i,t}^h + CrossRet_{i,t}, & D.Hedge_t = 1 \text{ and } D.Rebalance_t = 1 \\ P_{i,t-1} + EqRet_{i,t} + FXRet_{i,t}^u + CrossRet_{i,t}, & \text{Otherwise} \end{cases}$$

Stock index investment in NOK adjusted for hedging activity realization and portfolio rebalancing

$$Portfolio_t = \sum_{i=1}^4 P_{i,t}$$

Total portfolio

13.2.8 SCR Portfolio Variables

$$SCR_t = L_{C,t} - Diversification_t$$

SCR from currency exposure is given by the stand-alone potential losses from currency subtracted the gains from diversification

$$Diversification_t = L_{E,t} + L_{C,t} - L_t$$

Diversification gains

$$V_{E,t} = Portfolio_t$$

Value of equity positions (equity exposure) in the SCR computation

$$L_{E,t} = 0.39 * V_{E,t}$$

Loss potential from equity positions. 0.39 is the equity risk factor for OECD/EEA equities defined by EIOPA

$$V_{C,t} = \max[P_{i,t} - \sum_{i=1}^4 (h_i P_{i,t}^*), 0]$$

Value of currency positions (currency exposure) in the SCR computation

$$L_{C,t} = 0.27 * V_{C,t}$$

Loss potential from currency. 0.27 is the currency risk factor for all currencies defined by EIOPA

$$L_t = \sqrt{\begin{bmatrix} L_{E,t} & L_{C,t} \end{bmatrix} \begin{bmatrix} 1 & 0.25 \\ 0.25 & 1 \end{bmatrix} \begin{bmatrix} L_{E,t} \\ L_{C,t} \end{bmatrix}}$$

Total loss potential from equity and currency positions

13.2.9 Variables for $t = 0$

In the following section, all variable formulas hold for $t = 0$

$$\begin{bmatrix} w_{1,t} \\ w_{2,t} \\ w_{3,t} \\ w_{4,t} \end{bmatrix} = \begin{bmatrix} 0.30 \\ 0.50 \\ 0.15 \\ 0.05 \end{bmatrix}$$

The initial stock index weights are set according to a representative international equity allocation for Norwegian life insurers

$$P_{i,t} = w_{i,t} * Capital$$

The initial NOK value of each stock index investment is given by the initial weight multiplied with the initial capital employed in international equity

13.3 Foreign Exchange Rates Regressions

2003-2007					2010-2015				
EURNOK					EURNOK				
	IR	Oil	VIX	Const		IR	Oil	VIX	Const
Coeff	-0.2339**	-0.0076**	0.0072**	8.4848**	Coeff	-1.4380**	-0.0144**	-0.0040**	11.6877**
r2	54.27%				r2	77.18%			
USDNOK					USDNOK				
	IR	Oil	VIX	Const		IR	Oil	VIX	Const
Coeff	-0.0954**	-0.0276**	0.0174**	7.6540**	Coeff	-0.6681**	-0.0234**	0.0091**	9.4649**
r2	75.15%				r2	84.60%			
GBPNOK					GBPNOK				
	IR	Oil	VIX	Const		IR	Oil	VIX	Const
Coeff	-0.1765**	-0.0105**	-0.0092**	12.2587**	Coeff	-1.5556**	-0.0257**	0.0162**	14.1666**
r2	41.49%				r2	80.02%			
JPYNOK ⁽¹⁾					JPYNOK ⁽¹⁾				
	IR	Oil	VIX	Const		IR	Oil	VIX	Const
Coeff	-0.4257**	0.0018**	0.0540**	6.0981**	Coeff	-0.2623**	-0.0187**	0.0262**	7.0777**
r2	90.99%				r2	49.60%			

2008-2009				
EURNOK				
	IR	Oil	VIX	Const
Coeff	-0.5886**	-0.0085**	0.01441**	9.5403**
r2	82.16%			
USDNOK				
	IR	Oil	VIX	Const
Coeff	0.0222	-0.0177**	0.0171**	6.7826**
r2	90.83%			
GBPNOK				
	IR	Oil	VIX	Const
Coeff	-0.7420**	0.0001	0.02540**	9.9753**
r2	63.58%			
JPYNOK ⁽¹⁾				
	IR	Oil	VIX	Const
Coeff	-0.2027**	-0.0149**	0.0324**	7.0077**
r2	92.77%			

* p-value of coefficient is less than 0.10, ** p-value of coefficient is less than 0.05

⁽¹⁾The JPYNOK is expressed as the quoted 100JPY/NOK

Table 8 Regression output for drivers of the NOK

13.4 Sensitivity Analysis of Rebalancing Boundary

Rebalancing boundary	Hedged Portfolio Performance				
	0%	10%	20%	30%	40%
Average Return	4.61%	4.67%	4.52%	4.60%	4.64%
Standard Deviation	17.97%	17.98%	18.05%	18.01%	18.00%
Semideviation	14.42%	14.44%	14.54%	14.53%	14.54%
Number of rebalancings	25	10	2	2	0

Table 9 Sensitivity analysis of various performance measures with respect to the rebalancing boundary