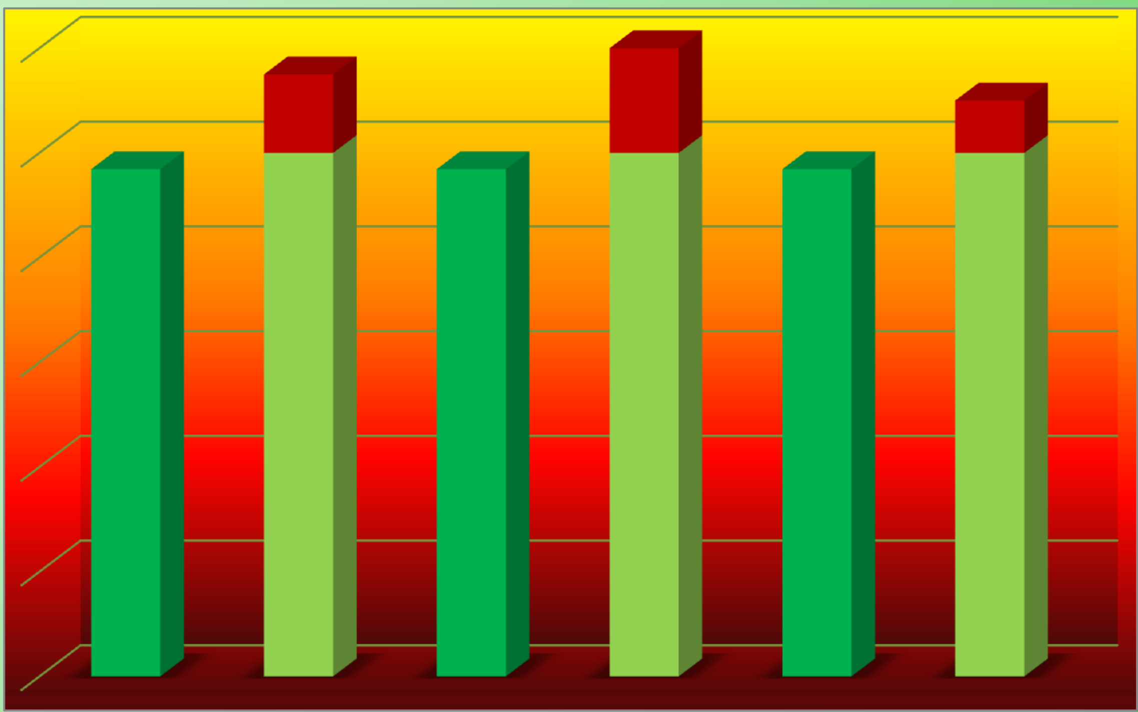
Testing the standard DNB model for calculation of solvency buffers for pension funds

Statistical argumentation for change to internal models and guideline for (partial) internal models



Master Thesis Financial Engineering and Management

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Management summary

To be able to meet their future obligations pension funds are required to have solvency buffers, which are designed to account for the risks pension funds are associated with. These required equity buffers (Vereist Eigen Vermogen, VEV) are determined by a standard model proposed by the Dutch regulator (DNB), which gives a certainty of 97.5% that a pension fund is able to meet its obligations over a period of one year. The DNB model is based on certain scenarios that can happen in one year time and are based on predetermined parameters. This model will be revised in 2015.

Research goal and main research question
Pension funds that have risks that are not covered by the standard model have the option to change to a (partial) internal model to measure the required amount of equity. This report gives statistical argumentation for the change to internal models. This is done by comparing the DNB model with a historical 97.5% Value-at-risk (VaR) model. This research gives an answer to the following main research question:

- Is the DNB model for calculation of VEV sufficient compared with a historical 97.5% VaR model or to which extension should it be replaced by a partial internal model?

Research method
In this research six synthetic (virtual) pension funds and the average pension fund in the Netherlands are used as input to test the DNB models. Every synthetic pension fund has its risk profile based on the asset mix of the pension fund and the interest hedge ratio, which are the main factors that determine the risk pension funds have. The values of VEV per pension fund as result of the current DNB model and the model in 2015 are tested in two ways. First the models are compared with a 97.5% Value-at-Risk (VaR) model based on historical simulation. With this model 415 expected future values of a portfolio of a pension fund are estimated using 415 10-day returns of market variables from a historical period (years 1997 till 2013). These 10-day returns are transformed into yearly profits and losses. The 10th worst simulated future loss is the amount of VEV that corresponds with a 97.5% confidence level of the VaR model, which is compared with results of VEV of the DNB model. Besides the comparison with the 97.5% VaR model individual risk factors of the DNB models are back-tested against historical movements of market variables to see if the models give a good estimation of the risk associated with these variables.

The DNB models are rejected (indicated by the color red in columns VEV DNB model in Table of results) if the value of VEV is not in the non-rejection region of the 97.5% VaR model. This non-rejection region is based on Kupiec's test, which is a statistical test that determines whether an observed frequency of exceptions is consistent with the number of expected exceptions according to the 97.5% VaR model. An exception occurs when the simulated loss is less than the 97.5% VaR confidence level. The non-rejection region is a confidence interval of the number of exceptions that are acceptable based on the Kupiec's test statistic, which is the critical value of a chi-square distribution with one degree of freedom and a confidence level of 97.5%. The lower boundary of the non-rejection region is the 19th worst simulated loss of the 97.5% VaR model and the higher boundary is the 5th worst simulated loss.

This leads to the following null-hypothesis and alternative hypothesis:

H_0: Value of VEV DNB model is in non-rejection region of the 97.5% VaR model
H_1: Value of VEV DNB model is outside non-rejection region of 97.5% VaR model

If the null-hypothesis is rejected the DNB model is rejected by Kupiec's test.

Results
The results show that for pension funds with low hedge ratios the value of VEV as result of the current DNB model is outside the non-rejection region and therefore the null-hypothesis is rejected. Comparing pension funds with the same asset mix, the pension fund with the lower hedge ratio (funds 1, 3, 5) is rejected, while the fund with the higher hedge ratio (pension funds 2, 4 and 6) is not rejected. This is because there is a significant difference between the amount of interest rate risk in the DNB models and the 97.5% VaR model, especially for pension funds with low hedge ratios.

Six synthetic pension funds and average pension fund in the Netherlands	Non-rejection region 97.5% VaR model		VEV DNB model (In billion Euros ; in %)			
	VEV in bln Euros	VEV in %	Not-rejected		Rejected	
			Current model		Model 2015	
1: High risk asset mix; 25% interest hedge ratio	219-375	23%-40%	169	18%	207	22%
2: High risk asset mix; 50% interest hedge ratio	149-261	16%-28%	153	16%	188	20%
3: Moderate risk asset mix; 50% interest hedge ratio	155-277	16%-29%	126	13%	166	18%
4: Moderate risk asset mix; 75% interest hedge ratio	99-184	10%-19%	109	12%	151	16%
5: Low risk asset mix; 75% interest hedge ratio	108-166	11%-18%	83	9%	123	13%
6: Low risk asset mix; 100% interest hedge ratio	55-99	6%-10%	71	8%	113	12%
7: Average Dutch fund; 40% interest hedge ratio	180-311	19%-33%	141	15%	181	19%

Table of results: Comparing VEV of DNB models with non-rejection/rejection region of the 97.5% VaR model

Based on the rejection of the DNB model for pension funds with low interest hedge ratios (pension funds 1, 3 and 5) the DNB model seems to underestimate *interest rate risk*. Results of the DNB model are based on the assumption that the returns of interest rates used to calculate the present value of fixed assets (bonds, interest rate swaps, forwards) and liabilities (future retirement obligations) are distributed normally. Back-tests of the returns of *euro swap rates* in years 1997-2013 show that these returns do not follow a normal distribution, especially for assets and liabilities with short term maturities (1-10 years). Besides that the interest rates in the historical back-test period have higher volatility than expected by the DNB model, this leads to a large difference of required equity for interest rate risk between the historical 97.5% VaR model and the DNB models.

Back-tests show that the scenarios for *credit risk* of the DNB model in 2015 overestimate credit risk especially for AAA rated assets. For pension fund six, with a large amount of fixed assets with credit rating AAA, the rejection of the DNB model in 2015 is a consequence of this overestimation of credit risk.

The risk scenarios in the DNB model are based on the assumption that returns of positions in the portfolio of a pension fund follow the normal distribution. Based on this research returns of *private equity and not-listed real estate* do not follow a normal distribution. Valuation of these assets does not happen frequently, which leads to long periods of low volatility and short periods of high volatility. Other positions that are not measured by the DNB model are *options*. The current DNB model does not include Vega risk, which is the risk related to the volatility of underlying assets of an option. Pension funds with a large weight of these positions in their asset mix should consider changing to an internal model.

Contents

Chapter 1: Problem identification and research method

In this chapter the design of this research is presented. Paragraph 1.1 consists of a general introduction. Besides that the goal of this research is presented. In paragraph 1.2 the main research question and other questions related the research problems are presented. Finally in paragraph 1.3 the method followed to answer the research questions is explained.

1.1 Introduction

Pension funds are associated with all kinds of risk. To make sure that they meet their obligations pension funds follow regulations of the Dutch Central Bank (DNB), which means that certain capital buffers should be present to account for risks. As of 2007 Dutch pension funds have to comply with a framework of rules called the FTK (financieel toetsingskader), in which a standard model is presented for the determination of the required equity (VEV, vereist eigen vermogen) related to the control rules Minimum Capital Requirements and Solvency Capital Requirements according to Solvency II. The DNB is going to refine the buffers used in the current FTK in 2015.

Pension funds make use of partial internal models when the standard DNB model does not give a good representation of the risk they endure. The choice to make a change from the standard model presented in FTK to partial internal models is their own responsibility. However this choice should be backed with arguments. K A S B A N K gives advice in this matter as service provider of risk management for pension funds. This leads to the following research goal:

Give the argumentation for changing from the standard DNB model to (partial) internal models for calculation of VEV.

Short summary of the standard DNB model

To understand the research questions posed in paragraph 1.2 a short introduction of the standard model is given in this paragraph. The current DNB model for the calculation of VEV consists of ten risk factors. First the value of each risk factor is determined separately based on certain scenarios that can happen within a year. The risk factors and calculation per risk factor can be seen in Table 1. Secondly the risk factors are combined in a square root formula. The parameters used for the calculation of VEV will be adjusted in 2015. The new parameters are calibrated with recent developments in the market taken into account. An extensive explanation of the calculation per risk factor and the square root formula is given in chapter 2.

Risk factors active investment risk, liquidity risk, concentration risk and operational risk are considered insignificant in the current model and have a value of zero in the formula. In 2015 the factor active investment risk (S7) will be added to the formula.

In the current DNB model the risk factors are combined in the following formula:

$$\sqrt{S_1^2 + S_2^2 + S_3^2 + S_4^2 + S_5^2 + S_6^2 + S_7^2 + S_8^2 + S_9^2 + S_{10}^2 + 2 * 0{,}65 * S_1 * S_2}$$

As can be seen in the formula a correlation is present between interest rate risk (S1) and equity risk (S2). In the model of 2015 a correlation is added between interest rate risk and credit risk (S5) and between equity risk and credit risk and the correlation between interest rate risk and equity risk is adjusted. These correlations are the result of extensive research and will be explained in chapter 2.

The outcome of this formula is the amount of VEV a pension fund should have to comply with according to the law (FTK).

Risk factor	Subfactors	Calculation risk factors current model	Calculation risk factors in 2015
Interest rate risk (S1)		VEV for interest risk is determined by the change of the interest curve (in this research the euro swap curve) according to factors based on maturities of assets and liabilities within a fund.	Same as current model
Equity risk (S2)	Equity Mature	Scenario with decrease of present value with 25%	Scenario with decrease of present value with 30%
	Equity emerging	Scenario with decrease of present value with 35%	Scenario with decrease of present value with 40%
	Private equity	Scenario with decrease of present value with 30%	Scenario with decrease of present value with 40%
	Real estate	Scenario with decrease of present value with 15%	Same as current model
Currency risk (S3)		Scenario with decrease present value of foreign currencies with 20%	Scenario with a decrease of present value of foreign currencies with 15%
Risk of commodities(S4)		Scenario with decrease of present value with 30% for commodities	Scenario with a decrease of present value with 35% for commodities
Credit risk (S5)	AAA	Relative increase of credit spread of 40%	Increase credit spread with 60bps
	AA	Relative increase of credit spread of 40%	Increase credit spread with 80bps
	A	Relative increase of credit spread of 40%	Increase credit spread with 130bps
	BBB	Relative increase of credit spread of 40%	Increase credit spread with 180bps
	≤BBB	Relative increase of credit spread of 40%	Increase credit spread with 530bps
Actuarial risk (S6)		Determined by uncertainty related to mortality risk+ a buffer for negative stochastic deviations in expected value mortality figures.	Same as current model
Active investment risk (S7)		Not applicable (value is zero in formula)	A multiplication of the tracking error(difference between results equity risk and benchmark) with the weight assets invested in equity in the portfolio
Liquidity risk(S8)		Not applicable (value is zero in formula)	Not applicable
Concentration risk(S9)		Not applicable (value is zero in formula)	Not applicable
Operational risk(S10)		Not applicable (value is zero in formula)	Not applicable

Table 1: Calculation scenarios per risk factor current DNB model and DNB model in 2015

1.2 Research questions

In relation to the goal of this research certain research questions should be answered. In this paragraph the related research questions are presented. These questions give an overview of the contents of this report.

Main research question

- Is the DNB model for calculation of VEV sufficient compared with a historical 97.5% VaR model or to which extension should it be replaced by a partial internal model?

Related questions

1. What is the explanation of the DNB model for the calculation of VEV of pension funds?
    - What are characteristics and parameters of the DNB model?
    - What are the scenarios used for determining the values of parameters?
    - What is the aggregation technique of the parameters to get an overall value for VEV?
2. What is the explanation of the theoretical methods used to test the DNB model?
    - What is the description of theoretical method?
    - Which tests are performed to test the DNB model?
3. What data is used as input for the tests?
    - How do you categorize the input data representing a Dutch pension fund?
    - Which historical input data is used for back-testing the parameters of the DNB model?
4. Does the DNB model give a good estimate of the risks associated with a pension fund?
    - Are the values of parameters of a 97.5% VaR model significantly different from the values determined by the DNB model?
    - Back-testing DNB parameters: Are the values of the parameters of the DNB model significantly different then values based on historical input data?
    - What are the reasons for deviations from the standard model?
5. If the standard model does not comply, how should it be extended to a partial internal model?
    - Which constraints should a partial internal model comply with?
    - Which risk factors of DNB model should be changed and how?
    - Which risk factors should be added to DNB model?

1.3 Research method

A certain method is followed to give an answer to the research questions. This paragraph will give an explanation of the method followed in this research.

- **Explanation of DNB model**

The answers to questions regarding the calculation of both the current DNB model and the future model implemented in 2015 can be found in documents on the DNB website[1]. In the DNB model the desired solvability of a pension fund is calculated using parameters per risk factor. The value of these parameters is determined making use of certain fixed scenarios. This model can be described as a parametric model.

- **Models to compare with DNB model**

The main research question gives motive to test the DNB model. Other models to calculate the amount of VEV are 97.5% VaR models based on the historical simulation method and the Monte Carlo simulation method. With historical simulation the future value of a variable is estimated using data from the past. If there is not enough information from the past to give a statistically significant estimation of parameters Monte Carlo simulation can be used to predict future values. With Monte Carlo simulation future values are predicted using current values of market variables and sampling from a multivariate normal probability distribution. Both historical simulation and Monte Carlo simulation method can be executed with a risk management software tool called Risk Metrics Riskmanager. In this research a calculation of the VEV for pension funds is done with both the DNB model as well as a 97.5% VaR model based on the historical simulation method. The choice for this method will be explained in chapter three.

- **Statistical tests for comparison models**

The outcomes of the models are compared using Kupiec's test and a conditional coverage test. These statistic tests result in a confidence interval for the number of exceptions (the number of times a simulated loss is bigger than the 97.5% VaR level of the historical simulation model) that is acceptable based on Kupiec's test statistic. If this statistic is higher than the critical value of a chi-square distribution with one degree of freedom and a confidence level of 97.5% the number of exceptions is not acceptable. When the outcome of the DNB model is outside the confidence interval of Kupiec's test, this leads to a rejection of the null hypothesis and acceptance of the alternative hypothesis, which are:

H_0: Value of VEV D NB model is within non-rejection region of the 97.5% VaR model
H_1: Value of VEV DNB model is outside non-rejection region of 97.5% VaR model

If the null hypothesis is rejected the outcome of the DNB model is significantly different than that of the historical VaR model. An extensive explanation of these tests is presented in chapter three as well.

- **Input data representing pension funds in the Netherlands**

K A S B A N K is a service provider for a number of pension funds and has records of the investments done by these funds. This data is used as input for testing the model. Besides this on the website of the Dutch Central Bank (DNB) figures of the total risk weighted assets of pension funds in the

[1] Herziening berekeningssystemathiek VEV; Advies inzake onderbouwing parameters FTK door DNB; Consultatie_doc FTK

Netherlands per quarter from 2007 till December 2012 are presented.[2] In this excel file these assets are divided into product categories (Equity, private equity, real estate, commodities etc.).

1.4 Structure of the report

To summarize the total report in this section the structure of this report is given. It is an explanation of the contents per chapter.

Chapter two gives an answer to research question one. It is an explanation of the current DNB model and the adjustments to this model that will be implemented in 2015.

In chapter three the theoretical models used to compare with the DNB model are explained. The DNB model can be compared with a parametric VaR model, a VaR model based on historical simulation or a VaR model based on Monte Carlo simulation. In this research the VaR model based on historical simulation is chosen for a comparison with the DNB model. The choice for this model is explained in chapter three. Besides this, chapter three contains an overview of the underlying calculations of the historical VaR model and an explanation of the options that can be chosen for the VaR reports in software tool RiskMetrics, which is used for the calculation of the VaR model. In paragraph 3.3 the statistical tests to compare the models are explained. The comparison of the models is done by both Kupiec's test and the conditional coverage test. Besides that a Basel framework used for back-testing VaR models is presented. This framework is another measure for the difference of outcomes of the DNB model and the historical VaR model.

In chapter four the input data of the six synthetic pension funds and the average pension fund in the Netherlands that will be used for testing the DNB model is described. The choice to use synthetic funds instead of real pension funds is explained in this chapter as well.

Chapter five is an overview of the results of the DNB model and the 97.5% historical VaR model. In paragraph 5.1 the amount of VEV per pension fund as result of the DNB models is compared with the 97.5% historical VaR model. This paragraph will show if the amount of VEV leads to a rejection of the null hypothesis, which means that the amount of VEV is outside the confidence interval based on Kupiec's test statistic. In paragraph 5.2 the same test is done for the amount of VEV per risk factor. In paragraph 5.3 the results of the parametric VaR model that can be used as a benchmark of the DNB model, because both models are based on a parametric calculation method, are shown. These results are not compared using statistic tests, but it is interesting to see if the results of the parametric VaR model are in line with the DNB model that will be implemented in 2015.

In chapter six the results of the DNB models are back-tested against historical benchmarks per risk factor. The scenarios of the DNB model per risk factor are back-tested using Kupiec's test. This chapter also shows if the risk associated with asset types in the historical VaR model is comparable with the related benchmarks per asset type.

In chapter seven suggestions for improvements of the standard model are presented. This can be done by adding risk factors or changing parameters of the model.

A final conclusion with the answer to the main research question is presented in chapter 8. In this chapter suggestion for further research are shown as well.

[2] DNB Table 8.9 Belegd vermogen voor risico pensioenfondsen

Chapter 2: Explanation of the current DNB model and expected adjustments to the model in 2015

This chapter explains the current DNB model for the calculation of VEV for a pension fund. First the characteristics of the DNB model are described in paragraph 2.1. In paragraph 2.2 the underlying parameters from which scenarios of the DNB model are derived are shown. In paragraph 2.3 the values of the parameters related to different risk factors of the current DNB model and the model that will be introduced in 2015 are explained. Finally in paragraph 2.4 the aggregation technique of risk factors is presented.

2.1 Characteristics of the standard DNB model

The DNB model is designed to give a value for a solvency buffer that a pension fund needs to have to be able to meet its obligations. This solvency buffer is an extra equity buffer on top of the other assets a pension funds has. The solvency buffer that is the result of the standard DNB model gives a certainty of 97.5% that a pension fund is able to meet its liabilities over a period of one year. With the aid of the standard model the sensitivity of a pension fund for certain scenarios like a decrease of the stock market or a change in the interest structure is tested. These scenarios are chosen in such a way that the likelihood of occurrence is once in 40 years relating to the 97.5% certainty level. The parameters of this model represent the changes that can happen in one year time and their values are based on historical observations.

2.2 Underlying Parameters of the DNB model

To make an accurate prediction of the changes in value of assets of pension funds certain parameters are taken into account. This paragraph introduces the underlying parameters used for the estimation of the parameters of the model and their values based on historical data.

The first underlying parameter is the expected return of fixed income assets, which is determined to be 5%. This return is based on figures of the twentieth century. From 1870 till 1960 the interest curve moves around the value of 5%, in the years 1960-1990 the long term interest rates increased exponentially to 15% and after 1990 the rate drops back to below 5%. The expectation is that the interest rate will be at a low level for a long time, because the government policy based on the control of inflation. The forward interest curve is directly observed from market data and is a good indicator for the future interest rate movements.

The second underlying parameter is the premium on equity used to determine parameters related to changes in equity. In the FTK the risk premium on equity is set on 3% and is based on a large literature study.[3] A premium of at most 3% does justice to the volatility of this parameter.

Pension funds invest about 10% of their assets in real estate. This percentage can be divided into 4% direct real estate and 6% indirect real estate. The indirect real estate can be considered as market equity. The risk premium for direct real estate is considered to be 1.5%.

[3] Advies inzake onderbouwing parameters FTK door DNB p. 13

Pension funds invest in commodities to diversify their asset portfolio. Investments in commodities are often based on index futures and options. The return on such a future is practically only based on the risk free premium.

Inflation rates are important to measure the change of value of interest related assets. The long term inflation rate is 2%. This is an expectation based on the policy of the European Central Bank to stabilize the price inflation.[4]

Return fixed income assets	**5%**
Risk premium equity	3%
Risk premium direct real estate	1.5%
Risk premium commodities	-
Long term inflation rate	2%

Table 2.1: Underlying parameters of the DNB model

2.3 Scenarios used for calculation of risk factors now and the expected parameter adjustments in 2015

In this paragraph the underlying calculation of the value of VEV needed per risk factor is presented. This calculation is based on a scenario per risk factor. These scenarios include the change of parameters related to a risk factor the next year after the reporting date.

Interest rate risk (S1)

The liabilities of a pension fund have longer modified duration than the fixed income assets. Because of this mismatch pension funds endure interest rate risk. If the interest rate decreases the value of the liabilities increases more than the value of the fixed income assets. This is why a certain buffer has to be present to account for this risk. For the standard VEV model the actual worth of assets and liabilities is determined using interest rate curves. For the current model DNB uses the nominal interest rate curve which is flat for long maturities. From the 30th of September 2012 the DNB is uses a curve based on ultimate forward rates (DNB UFR curve), which means a higher interest rate is used for assets with maturities longer than 20 years. This means that the liabilities in the far future are discounted with a high interest rate, which leads to a low present value of these liabilities. Both curves are presented in figure 2.1. In this research the assets and liabilities are discounted using the zero coupon Euro swap curve. The DNB UFR curve is not used in this research, because it does not represent real market movements for long term interest rates for assets and liabilities with long maturities.

[4] Advies inzake onderbouwing parameters FTK door DNB p. 17

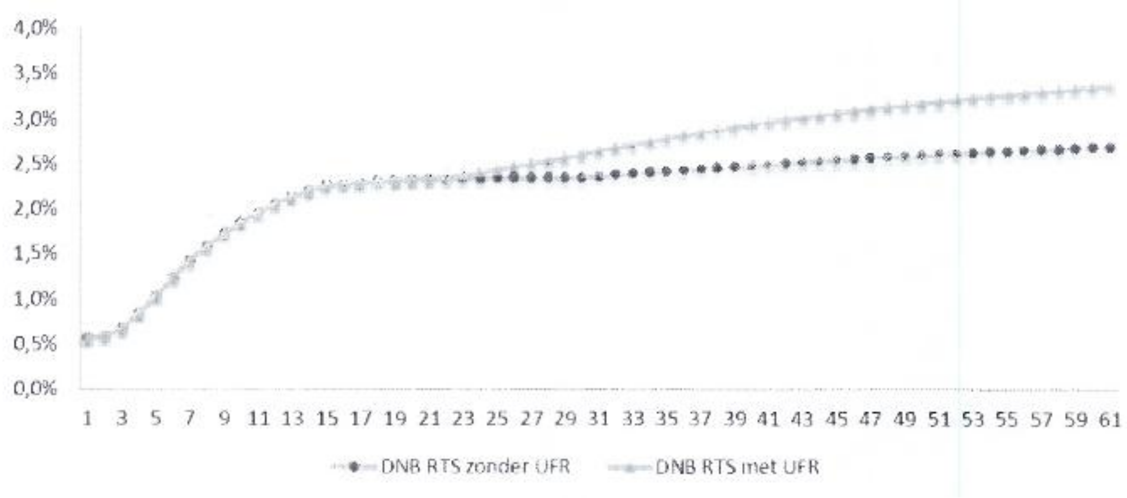

Figure 2.1: Interest rate curves based on nominal interest rates and ultimate forward rates (UFR) based on numbers 30-09-2012.

For the determination of a buffer for interest rate risk the sensitivity of the Euro swap curve is measured by multiplying the value of the curve with factors which are based on different maturities, both for an increase and decrease of the interest rate curve. The factors with maturities up to 25 years are shown in Table 2.2. These factors are based on a DNB calculation method.[5] For the estimation of the current interest rate factors the historical movements of two interest rate curves were used. The first curve is the 'Deutsche Zinstrukturkurve' (zero coupon) which is used for factors with maturities till ten years. Historical movements of this curve of years 1973-2003 are used as input for the estimation. The second curve is the Euribor curve (zero coupon) which is used for maturities of 1, 5, 10, 15, 20, 25 and 30 years. Historical movements of the Euribor curve of years 1997-2005 were used for the estimation of the DNB factors. The factors for maturities between 11 and 25 years are based on a composition of an extrapolation of the German rates and an interpolation of the Euribor rates. Relative changes of the interest rates are considered to be normally distributed[6].

[5] Herziening berekeningssystemathiek VEV, p.16 and p.20
[6] Advies inzake onderbouwing parameters FTK, p. 18-19

Maturity (years)	Current factor Increase	Current factor Decrease	Factor 2015 Increase	Factor 2015 Decrease
1	1.60	0.63	2.05	0.49
2	1.51	0.66	1.79	0.56
3	1.45	0.69	1.65	0.61
4	1.41	0.71	1.55	0.64
5	1.37	0.73	1.49	0.67
6	1.35	0.74	1.44	0.70
7	1.34	0.75	1.40	0.71
8	1.33	0.75	1.37	0.73
9	1.33	0.75	1.35	0.74
10	1.32	0.76	1.34	0.75
11	1.32	0.76	1.33	0.75
12	1.31	0.77	1.33	0.75
13	1.31	0.77	1.33	0.75
14	1.31	0.77	1.33	0.75
15	1.29	0.77	1.33	0.75
16	1.29	0.77	1.32	0.76
17	1.29	0.77	1.32	0.76
18	1.29	0.77	1.32	0.76
19	1.28	0.78	1.32	0.76
20	1.28	0.78	1.32	0.76
21	1.28	0.78	1.32	0.76
22	1.28	0.78	1.32	0.76
23	1.28	0.78	1.32	0.76
24	1.28	0.78	1.32	0.76
25	1.27	0.79	1.32	0.76
>25	1.27	0.79	1.32	0.76

Table 2.2: Interest rate factors DNB model for maturities of one year till 25 years

Equity risk (S2)
Equity risk can be divided into mature and emerging markets equity risk, real estate risk and alternative investments, which are investments in private equity and hedge funds.

To calculate the desired solvability the actual market value of all long and short positions in equity are multiplied by a decrease factor. For mature market equity a decrease of 25% is used. This 25% is based on returns and standard deviations retrieved from historical data from different countries in different time periods. Based on this data the expected yearly return for mature markets is 8%. A downward scenario with 97.5% significance is the expected return minus the standard deviation multiplied by 1.96. With an expected standard deviation of 17% based on historical data this means a decrease of $8 - 1.96 * 17 = -25\%$

For emerging market equity the MSCI emerging market index is used to find the historical standard deviation. Using historical data of the MSCI emerging market index gives the result: $8 - 1.96 * 24 = -39\%$ [7]. However in the DNB model a decrease factor of -35% is used for emerging markets. The used shock is less severe because of compensation for assumed correlation of one between mature market equity and emerging market equity.

[7] Advies inzake onderbouwing parameters FTK, p. 23

Alternative investments in private equity and hedge funds have higher standard deviations then mature market equity. A shock of -30% is used for this risk.

For real estate risk a scenario with a decrease of 15% is used. The valuation of assets in real estate is often done based on appraisal instead of transaction prices. A result of this valuation is that returns for real estate are smoothed. Research on the ROZ-IPD index in the years 1977-2002 gives a 7.5% standard deviation. Using this as input for the formula results in a shock of $6.5 - 1.96 * 7.5 = -8.5\%$. Based on the fact that these returns underestimate the real price movements of real estate, this is a limited correction, this is why a value of -15% is used for real estate. This shock is only used for the positions in direct real estate; stock listed real estate is considered as mature market shares.

Adjustments for equity risk parameters in 2015:

In the financial crisis values of stocks dropped more than anticipated. This is why the scenarios for equity risk are adjusted. For mature market equity the new scenario is a decrease of 30% of the market value within a year and for emerging markets and alternative investments the shock in the DNB model is adjusted to a decrease of 40%.

Currency risk (S3)
For investments in foreign currencies the risk factor currency risk plays a role. In the standard model a scenario is used with a 20% decrease of value for all foreign currencies. This factor is based on the exchange rates of a basket of currencies with weights based on positions of pension funds in foreign currencies in 2003 as can be seen in Table 2.3. The weight of the Argentine peso is a proxy for the sum of all currencies of emerging markets. Exchange rates of 1999-2004 are used for the calculation.[8]

Currency	Weight
US dollar	35%
British pound	24%
Argentine peso	13%
Japanese yen	8%
Swedish Krona	7%
Swiss franc	7%
Australian dollar	6%

Table 2.3: Weight of positions in foreign currencies Dutch pension funds in 2003

In 2015 the calculation of the scenarios for currency risk will be adjusted. On portfolios with well spread currency exposures a scenario with shock of -15% is executed. Because it is not clear if this is the worst-case scenario extra sensitivity analysis is needed. Exposure to currencies of emerging markets should be at most 30% of the total currency exposure, to be able to use this scenario. This scenario is not applicable for:

- Portfolios were the currency exposure exists of a single mature market. A shock of 20% is used for this case
- Portfolios were the currency exposure mainly exists of emerging markets. A shock of 30% is used for this case.

[8] Advies inzake onderbouwing parameters FTK, p. 30

- Portfolios were the currency exposure exists of one emerging market. A shock of 35% is used for this case.

Risk of commodities (S4)
The calculation of commodity risk is based on a scenario with a decrease of 30% of the present values of all positions in commodities in the portfolio of a pension fund. This scenario is based a series of monthly data of the Goldman Sachs Commodity Index (GSCI) in the years 1970-2001. The GSCI consists of a basket of 24 commodities. The volatility in this period was 17.8%; this relates to a 30% decrease factor[9]. Based on the current market situation this decrease is relatively low. In 2015 this decrease will be adjusted to 35%.

Credit risk (S5)
Credit risk is measured by the credit spread in the current DNB model. This is the effective return of the portfolio of assets depending on the credits worthiness of counterparties and the effective return of the same portfolio as if there were no risk involved. For example corporate bonds are compared with the riskless Euro swap curve to determine a credit spread. The surplus that is needed for credit risk is the increase of the credit spread with 40% so the credit spread of 100 basis points now will change to a credit spread of 140 basis points. The effect of the 40% increase is the surplus for credit risk. This relative increase of 40% is based on high sensitive credit risk investments. Standard & Poors corporate credit spreads (BBB and higher) in the years 1999-2004 are used to determine the shock. The observed volatility is 16%, with 97.5% confidence the shock for credit risk is 16*1.96 + 5%=37%. The 5% in the formula is the risk premium for fixed income assets. Due to the fact that funds also invest in non-rated corporate bonds in reality this shock is higher, hence the 40% factor.[10]

In 2015 the calculation of credit risk is depending on the credit rating of an asset. Credit risk will be calculated by multiplying the weight of assets of a certain credit rating by an absolute shock of a number of basis points. Table 2.4 shows the new parameters used for calculation of credit risk in 2015.

Credit rating	Absolute change in basis points
AAA	60bps
AA	80bps
A	130bps
BBB	180bps
≤BBB	530bps

Table 2.4: Absolute change of credit spread per credit rating

Actuarial risk (S6)
The actuarial risk is depending on abnormal negative variations in actuarial results within a year given the actual value of liabilities. The desired solvency buffer for this risk factor is different for a pension with or without survivor's pension. Besides these two risk groups the risk buffers depend on the average age of participants of the pension funds and the number of participants per fund. The formula is as follows: Risk buffer = $\sqrt{TSO^2 + NSA^2}$. Where TSO is an abbreviation of the Dutch word for future mortality risk and NSA stands for negative stochastic deviations of the expected value of future liabilities and is a percentage based on the size of a pension fund. The quantification of the

[9] Advies inzake onderbouwing parameters FTK, p. 31
[10] Advies inzake onderbouwing parameters FTK, p. 33

parameters in the formula is given in a table of a DNB document[11]. If a fund is large the buffer is relatively small.

Active investment risk (S7)
In 2015 there will be an additional buffer for active investment risk. In the years of crisis after 2008 pension funds have underperformed compared to their benchmarks. Because funding levels were decreasing pension fund managers where under high pressure to perform and took more risk than anticipated following their strategic portfolio. To account for this risk a certain buffer should be present. This buffer is the maximum expected loss that occurs with a probability of 2.5% within a year and will depend on the ex-ante tracking error. The ex-ante tracking error is the expected difference between results of equity risk in the portfolio of a pension fund and a benchmark that relates to this portfolio. To avoid operational costs tracking errors which are lower than one percent are not taken into account. The tracking error adjusted for costs multiplied by the weight of equity in the asset mix is the amount of VEV needed for active investment risk.

Additional risks: Liquidity risk (S8), concentration risk (S9) and operational risk (S10)
In addition to the risk mentioned above pension funds have extra risks that are considered to be zero in the standard method. However pension funds should mention these risks in their reports to the DNB. These risk are: Liquidity risk (S8); concentration risk (S9) and operational risk (S10).

Liquidity risk (S8) can be split into liquidity trading risk and liquidity funding risk. Liquidity trading risk occurs when a pension fund is not able to buy or sell an asset immediately when this is needed. The ability to sell depends on the volume of products that have to be sold and the timeframe in which the assets have to be sold. If a pension fund trades in rare products this can lead to big losses related to liquidity trading risk. Liquidity funding risk depends on the ability to meet cash needs if unexpected liabilities arise. Liquidity risk is partly taken into account, for example the difficulties in trading with private debt are already incorporated in the credit spread. Further then that liquidity risk is not taken into account in the capital requirements.

Concentration risk (S9) can occur when assets in the portfolio of a pension funds are related to the same market or geographical area. This risk is considered to be zero because the assets of portfolios of pension funds consist are considered to be well spread. However every pension fund should do some research regarding correlations between their assets and periodically report this to the DNB

"Operational risk (S10) is defined as the risk of loss resulting from inadequate or failed internal processes, people and systems or from external events." This risk cannot be measured in advance. Also this risk is often instable and does not have stand in proportion to the scale of operations.[12] Pension funds have to report their valuation of operational risk and discuss this with the DNB. The DNB wants to bring their knowledge to a higher level regarding this risk to be able to make a standardized method to account for this risk.

[11] Consultatie_doc bijlage 4 'tabellenboek voor risico-opslagen en solvabiliteit voor verzekeringstechnisch risico'.
[12] Consultatie_doc FTK, p. 68

Risk factor	Scenario	Parameters used for scenario	Data used to measure parameter values
Interest rate risk	Interest rate curve times shock factor	Nominal interest rate curve, shock factors	DNB calculation method for interest rate curve and shock factors[13]
Equity risk	Mature -25%	μ=8% σ=17%	MSCI 1970-2002 and Dimson et al 1900-2000[14]
	Emerging -35%	μ=8% σ=24%	MSCI emerging market index 1988-2006
	Private equity -30%	μ=8% σ=18%	US Pantheon International return 1988-2006
	Direct Real estate -20%	μ=9.7% σ=7.5%	ROZ-IPD index years 1977-2002
Currency risk	-20%	Currency basket weights and exchange rates	Weights based on positions pension funds 2003; exchange rates based on years 1999-2004
Commodity risk	-30%	μ=5% σ=17.8%	Goldman Sachs Commodity Index (GSCI) years 1970-2001
Credit risk	Credit spread +40%	Credit spread High risk investments with μ=5% and σ=16%	Standard & Poor's corporate credit spreads (BBB and higher) in the years 1999-2004
Actuarial risk	Risk buffer = $\sqrt{TSO^2 + NSA^2}$	TSO= future mortality risk NSA= negative stochastic deviations of future liabilities	DNB method for calculation of this risk factor[15]

Table 2.5: Overview of the historical data used to determine parameter values

2.4 Mathematical analysis of the standard formula aggregation technique

The DNB model consists of six risk factors with a positive value. These risk factors as introduced in the short summary in chapter one are aggregated in a square root formula. This calculation method is known as the hybrid approach[16] to derive the solvency capital requirement (SCR) for overall risk. The general form of the formula is $SCR_{overall} = \sqrt{\sum_{i,j} Corr_{i,j} * SCR_i * SCR_j}$, were $Corr_{i,j}$ denotes the correlation parameters and i and j run over all sub-factors. A simple assumption when aggregating loss distributions is that they are normally distributed. The formula above can be compared with a formula for aggregating standard deviations. The standard deviation of the total loss from n sources of risk is then, $\sigma_{total} = \sqrt{\sum_{i=1}^{n} \sum_{j=1}^{n} \sigma_i \sigma_j \rho_{ij}}$, where σ_i is the standard deviation of the loss from the ith source of risk and ρ_{ij} is the correlation between risk i and risk j. This approach tends to underestimate the capital requirement because it takes no account of the skewness and kurtosis of the loss distributions.[17] However this approach can give an approximate answer for the total amount of capital required.

[13] UFR methodiek voor de berekening van de rentetermijnstructuur
[14] Advies onderbouwing parameters FTK, p. 22
[15] Consultatie_doc bijlage 4 'tabellenboek voor risico-opslagen en solvabiliteit voor verzekeringstechnisch risico'.
[16] Hull, 2007. *Risk Management and Financial Institutions*, p. 433
[17] Hull, 2007. *Risk Management and Financial Institutions*, p. 433

Problems that can occur with this linear assumption are:

- The dependence between distributions is not linear; for example there are tail dependencies
- The shape of the marginal distributions is significantly different from the normal distribution

Tail dependence exists for market and credit risk. The financial crisis is a good example of this. Market parameters that have revealed no strong dependence in normal economic conditions showed strong adverse changes in these years of crisis. Where it can be assumed that the risks follow a multivariate normal distribution minimizing the aggregation error can be achieved by calibrating the correlation parameters in the standard formula as linear correlations.[18]

For applying the general formula on the pension fund risk factors some assumptions are made. The required solvency buffers (VEV) for mature market equity (Eq_M), emerging market equity (Eq_{Em}), private equity (Eq_P) and direct real estate (RE_D) are combined into one risk factor; equity risk. The underlying assumption is that with extreme shocks these components of equity risk have high correlation of 0.75[19]. The formula used for equity risk is:

$$Equity\ risk = \sqrt{\begin{gathered}(VEV\ Eq_M)^2 + (VEV\ Eq_{Em})^2 + (VEV\ Eq_P)^2 + (VEV\ RE_D)^2 + 2*0.75*(VEV\ Eq_M)*(VEV\ Eq_{Em}) + \\ 2*0.75*(VEV\ Eq_M)*(VEV\ Eq_P) + 2*0.75*(VEV\ Eq_M)*(VEV\ RE_D) + 2*0.75*(VEV\ Eq_{Em})*(VEV\ Eq_P) + \\ 2*0.75*(VEV\ Eq_{Em})*(VEV\ RE_D) + 2*0.75*(VEV\ Eq_P)*(VEV\ RE_D)\end{gathered}}$$

All risk factors have a correlation of zero except for interest rate risk (S_1) and equity risk (S_2). After research this correlation factor is determined to be 0.65. This is a rough estimate of the correlation.[20]

All risk factors are aggregated using the following formula:

$$\sqrt{S_1^2 + S_2^2 + S_3^2 + S_4^2 + S_5^2 + S_6^2 + 2*0{,}65*S_1*S_2}$$

The number that is the result of this formula is the actual value of VEV a pension fund should have. In 2015 new correlations between risk factors will be introduced, which will be explained in paragraph 2.5.

2.5 The expected DNB formula in 2015

Not only the individual risk factors are adjusted in 2015 but also the aggregation formula is changed in 2015. The expected formula according to DNB documentation that will be implemented in 2015 is expected to be:

$$\sqrt{S_1^2 + S_2^2 + S_3^2 + S_4^2 + S_5^2 + S_6^2 + S_7^2 + 2*0{,}4*S_1*S_2 + 2*0{,}4*S_1*S_5 + 2*0{,}5*\ S_2*S_5}$$

As can be seen in the formula the correlation between interest rate risk and equity risk will be changed to 0.4. Research shows that a peak in the correlation not necessarily coincides with a peak in the risk factors. Besides that correlations between interest rate risk and credit risk and between equity risk and credit risk are added. These correlations are based on perceived values measured in a

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[18] CEIOPS' Advice for Level 2 Implementing Measures on Solvency II: SCR STANDARD FORMULA Article 111(d) Correlations p. 6-10
[19] DNB Advies inzake onderbouwing parameters FTK p.27
[20] DNB Advies inzake onderbouwing parameters FTK p.37

research in times of stress, but are not the observed maximum values measured[21]. Besides the new correlations a risk factor for active investment risk (S7) is added to the formula. In the underlying period in many cases pension funds have met lower returns than the returns from their benchmarks. An important cause of this result is the degree of active investment in parts of the investment portfolio. This is why this new risk factor is introduced.[22]

[21] Herziening berekeningssystemathiek VEV, p. 4
[22] Herziening berekeningssystemathiek VEV, p. 4

Chapter 3: Explanation of the methods to test the DNB model according to literature

This chapter will give an overview of the methods used to test the DNB model for the calculation of VEV for pension funds. First in paragraph 3.1 a general introduction to these methods is given using risk management literature.[23] As described in chapter 1 the DNB model is tested using the software tool Risk Metrics Risk manager. This tool is chosen because it has a large number of options to calculate different VaRs. These options will be explained in paragraph 3.2. This paragraph gives an overview of all reports ran by Risk Metrics to test the standard model. Paragraph 3.3 explains which statistical tests are used to test the DNB models against the 97.5% VaR model and against historical benchmarks.

3.1 Introduction to VaR calculations

In the DNB model the expected changes of risk factors in one year time are calculated using predetermined parameters based on a certain return and volatility of the different assets. The change of parameters can also be measured by a Value-at-risk (VaR) approach. A VaR measure has the following form: "We are X percent certain that we will not lose more than V dollars in time T".[24] For the determination of VEV for pension funds the accuracy 'X' is 97.5%, the amount 'V' is the value of VEV needed and the time 'T' is one year. The VaR can be calculated from a probability distribution of losses during time T. The VaR is equal to the loss at the 97.5th percentile of the distribution. To determine the probability distribution the historical simulation approach can be used. With the historical simulation approach a future value of a portfolio is determined using historical data.

Example 1-day 99% VaR calculation with 501 days of historical data (Hull 2007)

Take for example the calculation of a 99% VaR for a portfolio using a one day time horizon. The first step is to identify market variables that affect the portfolio. For example market returns. Data is then collected about movements of these market values over the most recent 501 days. This data creates 500 scenarios which can happen the next day. Scenario 1 is the percentage changes of the input variables between day 0 and day 1 of the historical period, scenario 2 is the percentage change between day 1 and 2 etc. For each scenario the euro change of value of the portfolio is calculated. This defines a probability distribution for the daily loss between today and tomorrow. The 99% VaR is the 5th worst loss in the distribution.[25]

3.2 Testing the DNB model by running VaR reports in RiskMetrics Risk manager

This paragraph gives an overview of all the reports used to test the DNB model using data of the average pension fund in the Netherlands and six synthetic pension funds as input. The pension fund input data and the composition of the six synthetic pension funds will be explained in chapter 4. Reports will show both the result of the parametric calculation method and the historical simulation method in Risk Metrics. In Risk Metrics the results can be split into subgroups. These subgroups can be used to calculate the VaR per individual risk factor; however these individual VaRs cannot be aggregated to a total VaR. To determine the VaR per risk factor risk metrics distinguishes certain risk

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[23] Hull, 2007. *Risk Management and Financial Institutions*
[24] Hull, 2007 p.157
[25] Hull, 2007 p.249-250

types shown in Table 3.1. The VaR reports are split into VaRs per risktype to compare these VaRs with the values of VEV per risk factor in the DNB model.

Risk type RiskMetrics	Related risk factor
Equity risk	Equity risk
Interest rate (IR) market risk	Interest rate risk
Interest rate total risk	Interest rate risk and credit risk
Foreign exchange (FX) risk	Currency Risk
Commodity risk	Commodity Risk
Issuer specific risk	Credit Risk
Vega risk	Exposure of an option position to changes in Black-Scholes implied volatility

Table 3.1: Risk types risk metrics and their related risk factors

Issuer specific risk is related to the value of credit risk in the DNB model. Risk Metrics determines credit spread risk by taking the curve of an issuer of the bond, which is issuer specific risk. When this curve is not available in Risk Metrics the corporate sector curve related to a position is taken to determine the credit risk of a position. Figure 3.1 gives the evolution of corporate bond models in Risk Metrics until the fourth generation, which is the current model for the calculation of interest rate risk and credit risk. Interest rate risk is the risk related to movements of the riskless curve; in the 97.5% VaR model the zero coupon euro swap curve is used as riskless curve. The VaRs for IR market risk, equity risk, foreign exchange risk and commodity risk are directly compared with the values of their relating risk factors in the DNB model. Vega risk is the risk related to changes of an underlying position of an option. This risk is incorporated in the 97.5% VaR model in Risk Metrics, but is not present in the DNB model. However because the portfolio of the average pension fund in the Netherlands does not consist of many options the amount of VEV for Vega risk can be neglected.

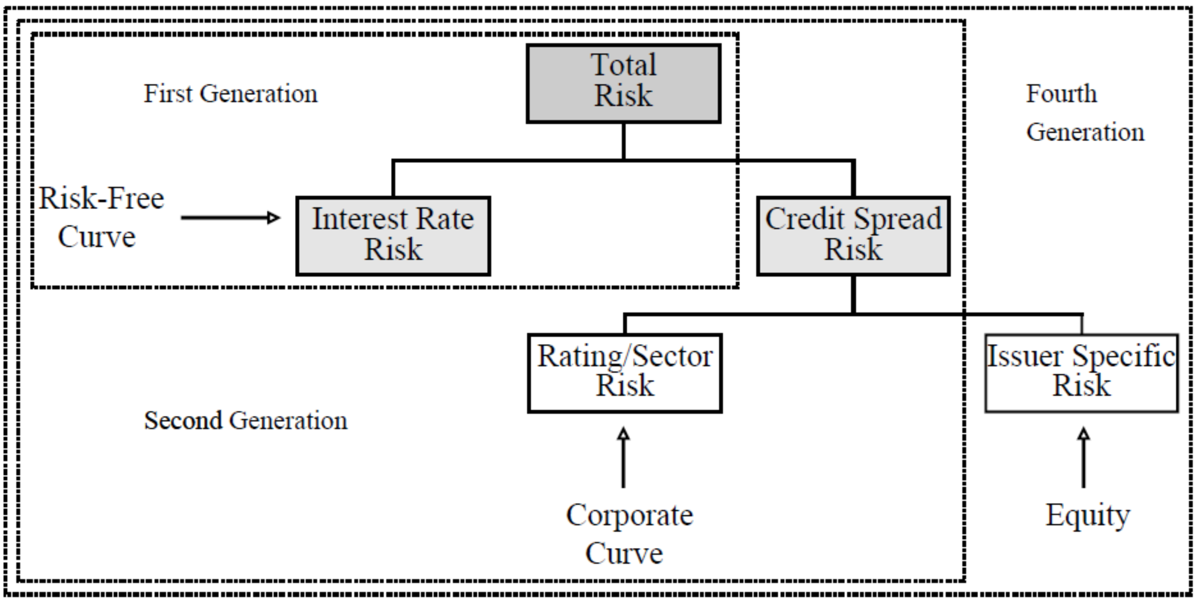

Figure 3.1: The evolution of corporate bond risk models in RiskMetrics[26]

[26] Mina & Ta. *Estimating issuer specific risk for corporate bonds*.p.8.From: http://help.riskmetrics.com/RiskManager3/Content/Release_Notes/IssuerSpecificRisk.pdf

Choices for running VaR reports

This section gives an explanation about the choices made for the VaR parameters in the VaR model. The selected options should be in line with the DNB model to make a good comparison.

Forecast horizon

The forecast horizon is the time over which the VaR is calculated. The VaRs for testing the DNB model have a forecast horizon of one year, because the DNB model also calculates a VEV value for one year ahead.

Confidence level

The confidence level of the VaR is the probability that the realized return of the forecast horizon is less than the VaR prediction. To test the standard model a confidence level of 97.5% is used. This is because the scenarios of the DNB model are also based on this confidence level.

Lookback-period

The lookback-period is the historical period over which the VaR is based. This period should be chosen with care, because different time periods will result in different VaRs. For example if one takes returns from 2008 the year the financial crisis started, the VaR will be relatively high compared to a VaR based on returns of the year 2007. In the VaR reports the returns from the 18th of July 1997 till the 31th of May 2013 are used. In this time period the years of the financial crisis are taken into account as well. These years will have a big influence on the VaR. A VaR from the time period 1997 till 2007 is calculated as well to see how much the recent years influence the VaR. Another important choice is which return horizon to use, which is the frequency of the return observations you wish to use to generate statistics. One popular combination is to use a 22-day return horizon (1-month) to compute 264-day (1-year) VaR. Scaling is therefore done by multiplying with the square-root of 12. For 1-year VaR this is perhaps more appropriate than simply scaling 1-day returns by the square-root of 264. In principle one could use 264-day returns to compute 264-day VaR but 50 years of data would be required. Scaling 4-5 years of monthly data seems like a good compromise.[27] However the popular combination of taking 22-day returns to get a 1-year VaR is not used in this research because with this method the 97.5% VaR is based on the 5th worse loss in the distribution of losses and to determine a VaR on this loss leads to very high VaR values, because of the high movements of market variables in the recent years. In the Var reports that are runned in RiskMetrics Risk manager the lookback-period is 16 years. The return period used in the VaR-reports is 10 days, which results in a total number of 415 returns. This number is large enough to get a statistically valid VaR result.

Choice of method

In RiskMetrics there is a choice between three methods to calculate the VaR. The parametric method calculates a standard deviation of the historical returns and uses this to get a VaR. The historical simulation method uses historical returns from the lookback-period to calculate a VaR directly from this distribution of returns. The third method is Monte Carlo simulation. With this method a

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[27] *RiskManager Volatility and correlation computations; Analysis horizon and Return horizon.* From: http://help.riskmetrics.com/RiskManager3

probability distribution for the future change of a market variable is generated using current values of market variables. An extensive explanation of the calculation methods is given later on in this paragraph. In this research both the parametric method as well as the historical simulation method is used for the VaR reports in Risk Metrics. The VaR based on historical simulation method is used to test the DNB models, because this method will give a realistic result of movements of market variables in the recent years, without the assumption of a distribution of returns. Because this method results in a VaR directly based on historical data; the value of this VaR highly depends on the chosen lookback-period. The Monte Carlo simulation method is not used, because there is enough historical information per risk factor to give a good estimation based on historical data. The result of the parametric method is based on the same underlying assumptions as the DNB models. However the output of the parametric method is based on real volatilities of positions and real correlations between positions, while the DNB model uses predetermined parameters. In the next two subsections of this paragraph the mathematical background of the calculation of the Parametric VaR and the historical simulated VaR are explained.

Overview of the choices made for the VaR model used for testing the DNB model

Choices made for 97.5% VaR model	
Forecast horizon	1 year
Confidence level	97.5%
Lookback period	7/18/1997 till 31/5/2013 (16 years)
Return horizon	10-day returns
Method	Historical simulation

Parametric VaR calculation method

The parametric VaR calculation method can be used for the calculation of linear instruments. All positions except for options in the asset mix of a pension fund are linear. In this section the general formula to compute VaR for linear instruments is provided. Consider a portfolio that consists of N positions and that each of the positions consists of one cash flow on which we have volatility and correlation forecasts. Denote the relative change in value of the nth position by $\delta_n r_{n,t}$. We can write the change in value of the portfolio, $r_{p,t}$, as

$r_{p,t} = \sum_{n=1}^{N} w_n * \delta_n * r_{n,t}$, where w_n is the total amount invested in the *n*th position.

For example, suppose that the total current market value of a portfolio is \$100 and that \$10 is allocated to the first position. It follows that w_1= \$10.

Now, suppose that the VaR forecast horizon is one day. In RiskMetrics, the 95% VaR on a portfolio of simple linear instruments can be computed by 1.65 times the standard deviation of $r_{p,t}$, the portfolio return, one day ahead. The 1.65 multiplication factor relates to a 95% confidence level, for a 97.5% VaR this factor is 1.96. According to Morgan & Reuters[28] the expression of VaR is given as follows:

$VaR_t = \sqrt{\sigma_{t|t-1} * \ R_{t|t-1} * \sigma_{t|t-1}^T}$ where

$\sigma_{t|t-1} = [1.65\sigma_{1|t-1}w_1\delta_1 \quad 1.65\sigma_{2|t-1}w_2\delta_2 \ldots \quad 1.65\sigma_{N|t-1}w_N\delta_N]$ is the individual VaR vector (1*N) and

[28] Risk metrics technical document 1996 p.126

$$R_{t|t-1} = \begin{bmatrix} 1 & \rho_{12,t|t-1} & \cdots & \rho_{1N,t|t-1} \\ \rho_{21,t|t-1} & 1 & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ \rho_{N1,t|t-1} & \cdots & \cdots & 1 \end{bmatrix}$$

is the correlation matrix of the returns on the underlying cash flows. The above computations are for portfolios whose returns are assumed to follow a conditional normal distribution.[29]

Historical Simulation method

The Historical Simulation method estimates VaR by taking actual historical rates and revalues every position for each change in market rates (i.e. each trial) according to user-specified start and end dates. There are no assumptions about normality or otherwise. Instead, distributions of underlying risk factors are taken exactly as found over the specified historical time period, the so-called lookback-period.

This method accurately prices all types of complex non-linear positions as well as simple linear instruments. It also provides a full distribution of potential portfolio gains and losses (which need not be symmetrical). If the underlying risk factors exhibit non-normal behavior such as fat-tails or mean-reversion, then the resulting VaR will include these effects. However, tail risk can only be examined if the historical data set includes tail events. That's why sampling history requires care in selection. Market conditions and currency devaluations may have occurred in the lookback-period, which led to dramatically shifting time series relationships.[30]

Overview of all reports

The reports done by RiskMetrics are shown in Table 3.2. The historical VaR reports in Table 3.2 test the risk factors interest rate risk, equity risk, currency risk, commodity risk and credit risk. Together with these VaR reports some extra reports will be done to give extra information.

First a report will give the present value of every position on 31th of December 2012. The positions that represent the average pension fund in the Netherlands are shown in Appendix B. This information gives an indication about which positions have a great influence on the result of the reports.

To test the volatility of the assets a standard deviation per position based on the same data period as the VaR reports is calculated. This standard deviation will be compared with standard deviations of related benchmarks in chapter 6 to see if the positions in the portfolio are representing the same amount of risk as their benchmarks.

As mentioned earlier in this paragraph the VaR of the portfolio is calculated using a matrix of correlations between positions. An extra report is done to show these correlations. To test if the correlation between the assets equity mature and emerging, real estate and private equity is really 75% as suggested in the DNB model a test is done to calculate correlations between asset types in different time periods.

[29] Risk metrics technical document 1996 p.126

[30] Risk methodologies from:http://help.riskmetrics.com/RiskManager3,

A parametric VaR is calculated to compare this with the results of the DNB model in 2015. In the DNB models most scenarios are based on volatilities of positions. The parametric VaR will show if the volatilities of positions in the lookback period are comparable to the volatilities of the DNB model in 2015, which is based on recent data.

To test interest rate sensitivity a parallel shift of the interest rate curve with a number of basis points is tested on the present value of the portfolios of different pension funds.

Report	Result	
Market value of positions	Shows the market value of all positions in the portfolio. Results are split into present value (PV)per asset type and PV per position	Appendix B
Standard deviation per position	Shows the standard deviation of every position in the portfolio	Chapter 6
Total Hist VaR	The total 97.5% 1-year VaR of the portfolio.	Par 5.1
Standalone Hist VaR per risk type	The VaR per risktype; this VaR cannot be aggregated to total VaR	Par 5.2
Correlations equity types	Historical correlations between all types of equity in the portfolio in different time periods	Par 5.2
Correlations risk types	Historical correlations between risk types in different time periods	Par 5.2
Parametric VaR per risk type	The VaR per asset type; this VaR cannot be aggregated to total VaR	Par 5.3
Interest rate curve shock	Shows value of the assets of the portfolio and the liabilities after a change of interest rate curve with a number of basis points	Par 5.2

Table 3.2: Overview of reports done by RiskMetrics and their results

Risk factors that are not tested by the historical VaR model

What remains is the testing of the risk factors actuarial risk (S6) and active investment risk (S7). Actuarial risk will not be tested in this research because large changes compared to the value in the DNB model are not expected. The value for active investment risk cannot be tested against historical information, because there is not enough data to give a statistically valid outcome. An approximation for the value of active investment risk for the average pension fund in the Netherlands will be explained in chapter 4.

Total VEV in relation to funding level of pension funds

To see the solvency buffer in perspective the amount of total VEV is presented as a percentage of the funding level. The funding level is the amount of assets needed to meet the future obligations. The minimum funding level according to Dutch regulation (FTK) is 105%, which means that the present value of the assets should be at least 5% larger than the present value of the liabilities. The required solvency buffer (VEV) is larger than the minimum solvency buffer. The total amount of VEV will be presented as percentage of the funding level to be able to compare different pension funds.

Solvency analysis average Dutch pension fund on 31th of December 2012		
	Amount (billion)	Funding level
Total liabilities	945	100%
Total assets	916	96.9%
Owner Equity (EV)	-29	
Minimum solvency buffer	47.25 (5%)	105%
Required solvency buffer (VEV)	153.7(16.3%)	116.3%[31]
Equity shortage, surplus (VEV)[32]	-182.7	

Table 3.3: Solvency analysis average Dutch pension fund

3.3 Back-testing VaR reports based on historical time period

To determine if the VaR estimates are accurate the forecasts should be tested. Back-testing is a statistical testing framework that consists of checking whether actual losses are in line with VaR forecasts. This can be done using Kupiecs' test, which will be explained next.

3.3.1 Kupiec's Proportion of failures (POF) test

Kupiec's (1995) test attempts to determine whether the observed frequency of exceptions is consistent with the proportion of expected exceptions according to the VaR model and chosen confidence interval. Under the null hypothesis that the model is "correct", the number of exceptions follows a binomial distribution. The probability of experiencing x or more exceptions if the model is correct is given by: $P((x|T,p) = (T/x)p^x(1-p)^{T-x}$; where T is the number of observations and p is the probability of an exception given a certain confidence interval. If the estimated probability is above the desired "null" significance level, we accept the model. If the estimated probability is below the significance level, we reject the model and conclude that it is not correct. We can conduct this test for loss and gain exceptions to determine how well the model predicts the frequency of losses and gains beyond VaR numbers.[33] Kupiec's loglikelyhood test statistic is as follows:

$$LR_{POF} = -2ln\left(\frac{(1-p)^{T-x}p^x}{\left[1-\left(\frac{x}{T}\right)\right]^{T-x}\left(\frac{x}{T}\right)^x}\right)$$

Kupiec's log-likelihood test-statistic[34]

LR_{POF} is chi-square distributed with one degree of freedom. If the test statistic is lower than the critical chi-square value relating to the 97.5% confidence level, the model passes the test. When the value is higher the model is rejected. In appendix D an example of the calculation of Kupiec's test values for 415 10-day returns is given. This is the number of returns that is used for the comparison of DNB models with the historical simulated returns as a result of the RiskMetrics 97.5% VaR model.

Measuring the number of exceptions

To measure the number of exceptions the VaRs of the portfolio should be tested against actual returns of their benchmarks. For example the VaR of mature equity is tested against returns of the

[31] Required funding level(VEV level)=(Total liabilities + required solvency buffer)/Total liabilities
[32] Equity shortage=Equity(EV)-Required solvency buffer
[33] C. Blanco& M.Oks.Backtesting VaR models: Quantitative and qualitative tests. p.4.
[34] Nieppola, O. *Backtesting Value-at-Risk models.*p.20

MSCI-world index. The back-testing framework consists of monthly exceptions over the years 1997-2013. Suppose the 1-year VaR of the assets is 25% of the market value of these assets. In this example a historical monthly return is counted as an exception if the return is less then $\frac{-25\%}{\sqrt{12}}$=-7.217%[35]. The expected total number of exceptions for a 97.5% confidence level is 2.5% times total number of months used for historical back testing. Too many exceptions indicate that either the model is understating VaR or the pension fund endures abnormal situations in one year time and is very unlucky. How do we decide which explanation is most likely? Such statistical testing framework must account for two types of error:

- Type 1 errors, which describe the probability of rejecting a correct model
- Type 2 errors, which describe the probability of not rejecting a model that is false[36]

Idealy, the VaR model has both low type 1 as well as type 2 errors. In practice one has to trade off one type of error against another. Most tests fix type 1 errors and structure the test to minimize type 2 errors.

3.3.2 Basel framework for backtesting VaR

The Basel committee has decided to use a traffic light approach to back-test a VaR. In this approach outcomes are classified into three categories: green, yellow and red zones. These categories are chosen to balance between type 1 and type 2 errors. The Basel framework is used to test 1-day 99% VaRs based on daily returns banks based on a historical period of 250 days. The accuracy of the VaR model is evaluated counting the number of exceptions. Table 3.4 shows the framework of the Basel traffic light approach and the adjusted framework for pension funds. This traffic light approach is used as a back-testing framework in chapter 6 for the pension fund 97.5% VEV levels. Pension funds have yearly VaRs, but to test the number of exceptions with yearly VaRs the number of observations is too small. That is why the yearly VaRs are divided by the square root of twelve to get monthly VaRs and to be able to count the number of exceptions of monthly VaRs in a historical period of 16 years (191 months). The cumulative probability is the probability of obtaining a given number or fewer exceptions when the model is correct (i.e. true coverage is 99%) The green zone consists of a number of exceptions with a cumulative probability smaller than 95%; the yellow zone begins at the point where cumulative probability exceeds 95% and the red zone begins at cumulative probability of 99.99%.[37]

Assuming the 1-day 97.5% VaR model is correct the expected number of exceptions is 5. If there are zero to eight exceptions observed the model falls into the green zone and is defined to be accurate, because the probability the model is incorrect is low. The yellow zone consists of outcomes between nine and thirteen. These outcomes could be produced by both accurate and inaccurate models with relatively high probability. Most of the models are inaccurate but if a pension fund can demonstrate that the number of exceptions is high due to bad luck and the assumptions of the VaR model are fundamentally correct supervisors may revise their requirements.[38] A number of exceptions relating to the red zone indicates that there is a very small probability that an accurate model produces this number of exceptions, so the VaR model is automatically rejected.

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[35] Square root rule: A 1-year VaR can be turned into a N-year VaR by multiplying the VaR with $\sqrt{N}$
[36] Financial Risk Manager Handbook 2nd ed. p.680
[37] Nieppola, O. *Backtesting Value-at-Risk models.*p.24
[38] Nieppola, O. *Backtesting Value-at-Risk models.*p.25

Basel framework (99% 1-day VaR; N=250)			Basel framework adjusted for pension funds (97.5% 1-month VaR; N=190)		
Zone	# of exceptions(N=250)	Cumulative probability	Zone	# of exceptions(N=191)	Cumulative probability
green	0	0.081059	green	0	0.008145
	1	0.285752		1	0.047824
	2	0.543169		2	0.143971
	3	0.758117		3	0.298462
	4	0.892188		4	0.483654
yellow	5	0.958817		5	0.660299
	6	0.986299		6	0.799954
	7	0.995975		7	0.89408
	8	0.998943		8	0.949289
	9	0.99975	yellow	9	0.977916
red	10	0.999946		10	0.991202
	11	1		11	0.996776
	12	1		12	0.998908
	13	1		13	0.999657
	14	1	red	14	0.999900
	15	1		15	0.999972
	16	1		16	1
	17 or more	1		17 or more	1

Table 3.4: Traffic light approach; Basel framework and relating pension fund framework

3.3.3 Christoffersen's interval forecast test

The Basel traffic light approach and Kupiec's POF-test do not take into account the independence of the exceptions. Clustering of exceptions is something that VaR users want to be able to detect since large losses occurring in rapid succession are more likely to lead to disastrous events than individual exceptions taking place every now and then[39]. The clustering of exceptions suggests that losses on successive days are not independent, this is called bunching[40]. Christoffersen has developed a test with the same log-likelihood framework as the Kupiecs test, but extents this with a statistic which determines the independence of exceptions. Christoffersen's interval forecast test measures if the probability of an exception on any month depends on the outcome of the previous month.

O. Nieppola describes the Christoffersen test as follows[41]:

The test is carried out by first defining an indicator variable that gets a value of 1 if VaR is exceeded and value of 0 if VaR is not exceeded:

$$I_t = \begin{cases} 1, & \text{if exception occurs} \\ 0, & \text{if no exception occurs} \end{cases}$$

Then define n_{ij} as the number of times j occurred assuming that i occurred the previous day. The outcome can be displayed in the following 2x2 table:

[39] Christoffersen & Pelletier, *Backtesting Value-at-Risk: A Duration-Based Approach.* 2004.
[40] Hull, 2007. *Risk Management and Financial Institutions*, p. 171
[41] Nieppola, O. *Backtesting Value-at-Risk models.*p.27-28

	$I_{t-1} = 0$	$I_{t-1} = 1$	
$I_t = 0$	n_{00}	n_{10}	$n_{00} + n_{10}$
$I_t = 1$	n_{01}	n_{11}	$n_{01} + n_{11}$
	$n_{00} + n_{01}$	$n_{10} + n_{11}$	N

In addition let π_i represent the probability that an exception occurs conditional on the state i in the previous month:

$$\pi_0 = \frac{n_{01}}{n_{00} + n_{01}}, \qquad \pi_1 = \frac{n_{11}}{n_{10} + n_{11}} \qquad and \qquad \pi = \frac{n_{01} + n_{11}}{n_{00} + n_{01} + n_{10} + n_{11}}$$

If the model is accurate the difference between π_0 and $\pi_1$should be around zero. The relevant test statistic for independence of exceptions is a log likelihood-ratio(LR_{ind}):

$$LR_{ind} = -2ln\left(\frac{(1-\pi)^{n_{00}+n_{10}}\pi^{n_{01}+n_{11}}}{(1-\pi_0)^{n_{00}}\pi_0{}^{n_{01}}(1-\pi_1)^{n_{10}}\pi_1{}^{n_{11}}}\right)$$

By combining this independence statistic with Kupiec's test we obtain a joint test that has conditional coverage; i.e. it examines both properties of a good VaR model, the correct failure rate and independence of exceptions;

$$LR_{cc} = LR_{POF} + LR_{ind}$$

LR_{cc} is chi-square distributed with two degrees of freedom, since there are two statistics in the test. If the test value is lower than the corresponding chi-square critical value the model passes the test. Higher values lead to the rejection of the model. The critical value that corresponds to a 97.5% confidence level is 7.38.

Overview of back-tests

In Table 3.5 an overview of all back-tests that are performed in this research is shown. The results of these back-tests will be shown in chapter 6.

Back-tests per risk type	Paragraph	Historical benchmark	Data benchmark
VEV Interest rate risk	6.1	Euro swap curve	Monthly returns 1997-2013
VEV Equity mature market	6.2	MSCI world index	Monthly returns 1997-2013
VEV Equity emerging market	6.2	MSCI emerging market index	Monthly returns 1997-2013
VEV Indirect real estate	6.2	EPRA real estate index	Monthly returns 2002-2013
VEV Alternative investments	6.2	Societé generale PRIVEX	Monthly returns 2004-2013
VEV Currency risk	6.3	Exchange rates per currency	Monthly returns 1997-2013
VEV Commodity risk	6.4	ACWI Commodity producers index	Monthly returns 1999-2013
VEV Credit risk	6.5	Barclays Euro-aggregate credit ratings	Monthly credit spreads per credit rating 2003-2013

Table3.5: Overview of VEV results that will be back-tested in chapter 6

Chapter 4: Determination of the pension fund input data for testing the DNB model

To test to DNB model pension fund input data is needed to determine the historical changes in risk factors. This chapter first gives a categorization of pension funds based on asset mix and interest hedge ratio in paragraph 4.1 and an overview of the input data per risk factor in paragraph 4.2.

4.1 Categorizing pension funds based on asset mix and hedge ratio

Because different pension funds are related to different amounts of risk a distinction is made between six synthetic pension funds. This categorisation of pension funds is chosen because there is a limited amount of time available for this research and it takes too much time to use the real positions of individual Dutch pension funds as input for the Risk Metrics VaR model.

Every synthetic pension fund has its own risk profile. According to expert opinions[42] the two main factors to distinguish pension funds from each other are the interest hedge ratio and the asset mix. The interest hedge ratio is the percentage of interest rate related assets that is hedged and is therefore not sensitive to changes in the interest rate. The riskiness of an asset mix mostly depends on the percentage of fixed assets in the total asset mix. Pension funds with a large percentage of fixed income assets in their portfolio are considered less risky than funds with a low percentage of fixed income assets. Pension funds with relatively large percentages of mature and emerging market equity, private equity and commodities are considered risky. There is a relationship between the size of a pension fund and the risk of an asset mix. Large funds often have more investments in assets that are considered risky than small pension funds.

Table 4.1 shows the different pension funds based on asset mix and hedge ratio. A distinction is made between high, moderate and low risk asset mixes. These asset mixes are determined by looking at asset mixes of pension funds in the Netherlands, splitting these pension funds into three groups and taking the averages per group. The asset mixes and hedge ratios per individual pension fund are taken from annual reports of a large percentage of Dutch pension funds from 2010 and 2011.There is a relation between asset mixes and hedge ratios. The funds with a high risk asset mix have relatively low hedge ratios. A distinction is made between high risk funds with a low hedge ratio (25%) and high risk funds with a moderate hedge ratio (50%). For funds with a moderate asset mix a distinction is made between funds with a moderate hedge ratio (50%) and a relatively high hedge ratio (75%). For the low risk funds a distinction is made between funds with a relatively high hedge ratio (75%) and funds that completely or almost completely hedge their interest rate risk (100% hedge ratio). The column other assets in Table 4.1 consists of private equity, hedge funds, commodities and some remaining assets. On average about 70% of other assets are investments in private equity and hedge funds, 10-20% is invested in commodities and the remaining assets are liquid assets like securities and cash.

[42] Ard de Wit, head of institutional risk management K A S B A N K, suggested this categorization method because interest rate risk and business risk are the two risk factors that have the largest influence on the amount of VEV. The interest hedge ratio relates to interest rate risk and the asset mix relates to business risk

Pension fund	Average asset mix					Hedge ratio's (%)
	Degree of Risk asset mix	Equity (%)	Fixed assets (%)	Real estate (%)	Other assets (%)	
1	High risk asset mix	35	45	10	10	25
2						50
3	Moderate asset mix	25	60	10	5	50
4						75
5	Low risk asset mix	25	70	4	1	75
6						100
7	Average Dutch pension fund	30	55	10	5	40

Table 4.1: Asset mix and hedge ratios synthetic pension funds

Table 4.2 shows the asset mix of the average pension fund in the Netherlands based on Table 8.9 on the DNB site. The average pension fund in the Netherlands has an interest hedge ratio of 40%. Synthetic positions of assets and liabilities are added in Risk Metrics to achieve a portfolio that is similar to the asset mix of the average pension fund in the Netherlands. These positions that represent the average Dutch pension fund are used as starting point for the input for the six synthetic pension funds. To attain the average asset mixes per pension fund positions are added to the portfolio and removed from the portfolio. For example for the pension funds with a high risk asset mix, positions of equity will be added to reach the 35% average of equity for this fund and positions of fixed assets will be removed to reach the 45% of fixed assets.

Asset mix average pension fund 12-31-2012		
Asset type	Percentage	Market value(mln Euros)
Equity mature & emerging	29.3%	268,853
	80% Mature markets	213,091
	20% Emerging markets	55,762
Fixed assets	55.2%	506,157
Real estate	9.0%	82,752
	17.3% Direct; 82.7% Indirect	14,374; 68,378
	41% Listed; 59% Not-listed	48,518; 34,144
Private equity & hedge funds	7.4%	67,895
Commodities	0.2%	1,474
Other investments	-1.1%	(10,258)
Total assets	100%	916,874

Table 4.2; Asset mix of the average pension fund in the Netherlands on 31th of December 2012

The six pension funds and the average Dutch pension fund will be input for the tests described in chapter 3. One would expect that fund one has the highest value of VEV, because this fund is considered to have the highest risk. Results of the tests will be shown in chapter 5.

4.2 Input data assets and liabilities per risk factor

Besides input data of average asset mixes and hedge ratios of pension funds in the Netherlands this paragraph gives an overview of the input of all assets per risk factor in the DNB models.

Assets and liabilities related to interest rate risk (S1)

Bonds
The largest percentage of fixed income assets in the portfolio of the average pension fund of the Netherlands are bonds. This group of bonds can be divided into government bonds and corporate bonds. As the interest rate rises the market price of bonds falls and vice versa. For example, a 5% bond is worth more if interest rates decrease since the bondholder receives a fixed rate of return relative to the market, which is offering a lower rate of return as a result of the decrease in rates.

Foreign exchange forwards
To hedge the risk of positions in foreign currencies pension funds invest in foreign exchange forwards. FX forwards are contracts to buy/sell a fixed amount of a foreign currency at a fixed price in the future, therefore these instruments are sensitive to movements in interest rate. Pension funds in the Netherlands invest in forwards to hedge the US dollar, Japanese Yen, British Pound and the Swiss Franc. Details about the hedges will be given in the paragraph for currency risk exposure.

Interest rate swaps
As explained earlier hedging of interest related assets is done using interest rate swaps, which guarantee a fixed interest rate on a future date. With interest rate swaps the gap of durations of future liabilities and the fixed assets becomes smaller. The average duration of the fixed income assets of the average pension fund in the Netherlands is 7.9 years, with an interest swap with duration of 21.4 years the duration of the fixed assets becomes 13.8 years.

Distribution of future liabilities
As input for the liabilities of a pension fund the value of Table 8.8[43] on the site of the DNB is used for calculation of the expected retirement obligations per year. The total liabilities in 2012 quartile four are 899.988mln Euros. These liabilities are spread over a horizon of 88 years. The Euro swap curve is also used to discount the future liabilities. The distribution of the retirement obligations is presented in figure 4.1. The average duration of these cash flows is 17.4 years.

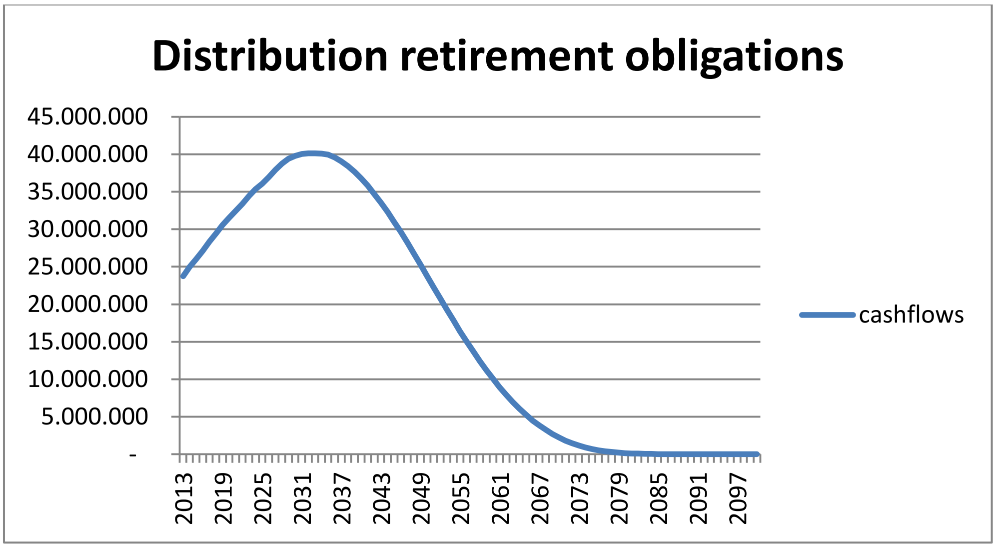


Figure 4.1: Distribution of future retirement obligations

[43] DNB. *Table 8.8 Geraamde dekkingsgraad*.

Currency risk exposure (S3)

Currency risk will be tested by the exposure of assets in the portfolio of the average pension fund to foreign currencies. This exposure is determined by a basket of foreign currencies with certain weights. Table 8.9.1 on the DNB website shows the weight of assets of the average Dutch pension fund invested in Euros is 52%. The other 48% are assets in foreign currencies. The weights for individual currencies of the other 48% assets are determined by taking the weights of these currencies from the asset mix of the MCSI world index of January 2011 excluding the Euro and multiplying these weights by 48%. This is approximation of the weight of assets per foreign currency in the average pension fund in the Netherlands. The result of this approximation is a basket with unhedged assets of foreign currencies. However most of the pension funds completely hedge the Dollar, and partly hedge the British Pound, Japanese Yen and Swiss Franc. The other currencies have a small weight in the total portfolio of assets and are therefore often not hedged. The hedge factors used for different currencies are an average based on hedge factors in annual reports of Dutch pension funds in 2011. The formula to calculate the final weight for the exposure per foreign currency is:

$$Weight_{Final} = (1 - hedge\ factor) * Weight_{Currency}$$

Table 4.3 gives an overview of all the currencies in the basket of the 97.5% VaR model and their weights with the hedge factors taken into account. The weight for the dollar is the sum of the assets related to the American dollar, the Hongkong dollar and the Canadian dollar, because their historical rates are strongly correlated. For the same reasons the weight for the Swedish Krona represents the weights for the Swedish Krona, the Norwegian Krone and the Danish Krone. Also the column with the weight used for the scenario of the DNB in the standard model is shown. As can be seen the weights in the basket of the 97.5% VaR model based on figures in 2011 have a different distribution then the basket of the DNB model derived from figures of positions of pension funds in 2003. It will be interesting to see if this change has an influence on the parameter used in this scenario. For every currency in the basket historical exchange rates between these currencies and the euro are used to test the historical movements in these rates and thus the risk involved with investing in assets in foreign currencies.

Foreign currencies in basket	Hedge factor	Weight basket 97.5% VaR model	Weight basket DNB model
Dollar	95%	23	35
British Pound	85%	15	24
Brazilian Real	-	16[44]	13[45]
Swedish Krona	-	15	7
Japanese Yen	80%	8	8
Swiss Franc	50%	13	7
Australian Dollar	-	10	6

Table 4.3: Basket of currencies and their weights

[44] This weight represents the weight of assets in emerging markets

[45] In the DNB model this is the weight of the Argentine Peso representing the weight of assets in emerging markets

Credit exposure; credit ratings of fixed income assets (S5)

To determine the credit exposure of fixed income assets these assets are divided into categories based on their credit ratings. In the DNB model the consequences of an absolute change to the credit spread per category are used to determine the amount of VEV for credit risk. The distribution of assets per credit rating based on the DNB average mix can be seen in Table 4.4. The value of assets smaller then BBB is the sum of assets smaller then BBB and the not rated assets.[46]This distribution is used as input for all tests relating to credit risk.

Credit rating	Percentage of fixed assets
AAA	45
AA	22
A	9.5
BBB	12.5
<BBB	11

Table 4.4: Percentage of fixed assets per credit rating

Input parameters actuarial risk (S6)

To measure the value of actuarial risk in the DNB model some characteristics of the participants of pension funds are needed. These characteristics are the type of pension, the number of participants in a fund, the average age of participants and their retirement age. Two types of pension are old age pension with and without survivors' pension. Pensions with survivors' pension relate to higher obligations. In 2011 the total number of participants in pension funds in the Netherlands was 14.448.338 and their average age was 43.7 years[47]. The retirement age used in the DNB model is 65 years.

Determining the tracking error for active investment risk (S7)

The value of active investment risk is based on the tracking error, which is the difference of the performance of a pension fund and their benchmarks. The tracking error is calculated for all listed equity. The actual tracking error is the standard deviation of the difference of performance compared to the benchmarks multiplied by 1.96 to get a 97.5% confidence level. The value of VEV is the tracking error with an adjustment for the costs which are measured by the total expense ratio (TER) multiplied by the weight of assets invested in equity. Because investment costs have a high influence on the tracking error, they are explicitly taken into account. An indication for the percentage of VEV for active investment risk based on different tracking errors and TERs is given in Table 4.5. This table is taken from a DNB document[48] and is based on weighted averages of pension funds. The column for S7 is an indication of the amount of VEV for active investment risk per pension fund. As can be seen pension funds with high tracking errors have a relatively high percentage of S7. In 2015 active investment risk should be incorporated in the DNB model. From Table 4.5 you can conclude that the higher the tracking error the lower the influence of the costs on the total percentage of S7.

[46] Asset <BBB have weight of 7% and not rated assets 4%
[47] DNB. Table 8.7 *Demografie*
[48] Herziening berekeningssystematiek VEV, p.13

Degree of risk	97.5% Tracking error	TER	% S7 of the VEV
Low	2.0	0.5	1.5%
Medium	5.0	1.5	4.6%
High	8.0	2.0	7.6%

Table 4.5: Percentage of VEV in relation with tracking errors and TERs

Chapter 5: Comparing the DNB models with the 97.5% VaR model

This chapter shows the results of all methods used for the calculation of solvency buffers (VEV) for the six synthetic pension funds and the average pension fund in the Netherlands. In paragraph 5.1 the total amount of VEV as result of the 97.5% VaR model based on historical simulation is compared with the total amount of VEV from the DNB models. In paragraph 5.2 the amount of VEV per individual risk factor and the tests for correlations between risk factors are presented. Paragraph 5.3 shows the comparison between the DNB models and a parametric historical VaR method, which is based on the same underlying assumptions as the DNB models. This comparison with the parametric VaR method is done to see if the adjustments of the DNB model in 2015 are realistic based on a recent period (years 1997-2013).

Options chosen for VaR model

In Table 5.1 an overview of the choices made for the historical VaR model is shown. The forecast period of the VaR model is one year, the confidence level is 97.5% and the lookback-period is 16 years. The 97.5% VaR is calculated using 10-day returns from 7/18/1997 till 5/31/2013. For every risk factor the equity buffers of the different models are compared with the outcomes of a historical simulation for the average pension fund in the Netherlands based on 10-day returns between 1997 and 2013. Based on these historical 10-day returns a yearly profit or loss scenario is calculated. In an output report of the simulated yearly profits/losses the 415 outcomes are then sorted from smallest to largest. For the three models per risk factor the 25 highest yearly simulated losses of the average pension fund in the Netherlands are shown. The number of exceptions, which is the number of times a loss is lower than the VaR level of the model, are shown as well. This number is used for the Kupiec's test and the Basel traffic light approach to determine if the VEV model is rejected or not.

Choices made for 97.5% VaR model	
Forecast horizon	1 year
Confidence level	97.5%
Lookback period	7/18/1997 till 31/5/2013 (16 years)
Return horizon	10-day returns
Method	Historical simulation

Table 5.1: Overview of the choices made for 97.5% historical VaR model

Non-rejection regions Kupiec's test and Basel traffic light approach

The 97.5% VaR model has an expected number of exceptions of 10. This is the number of simulated profits/losses (415) multiplied by 0.025. According to Kupiec's test a model is not rejected if the number of exceptions is between 5 and 18.This acceptation region is indicated by the green zone in the output tables in paragraph 5.1 and 5.2. If the number of exceptions is on the border of this range a conditional coverage test is done as well, which takes the dependence between exceptions into account. The maximum number of exceptions that is accepted by the Basel framework is 15, also indicated by a green zone. Models that have a number of exceptions between 16 and 23 are placed in the yellow zone. This means that if there is a good explanation why the model has too many exceptions the model can be accepted, if this is not the case the model is rejected. Models with a number of 24 exceptions and more are always rejected by the Basel framework.

The outcomes of the tests of the average pension fund in the Netherlands are very similar to the results of the tests of the high, moderate and low risk pension funds. The VaR levels of the high risk pension fund in general are higher and the VaR levels of the low risk pension fund are lower, but the number of exceptions of the six pension funds can be compared with the number of exceptions of the average Dutch pension fund. For a better overview of the results only the simulated losses of the average pension fund are shown, unless there is a significant difference in test values of pension funds.

5.1 Comparing total amount of VEV using the DNB model now, DNB model 2015 and the RiskMetrics 97.5% historical VaR method

In this paragraph the total amount of VEV as a results of the current DNB model, the DNB model that will be used in 2015 and the 97.5% historical VaR model are shown.

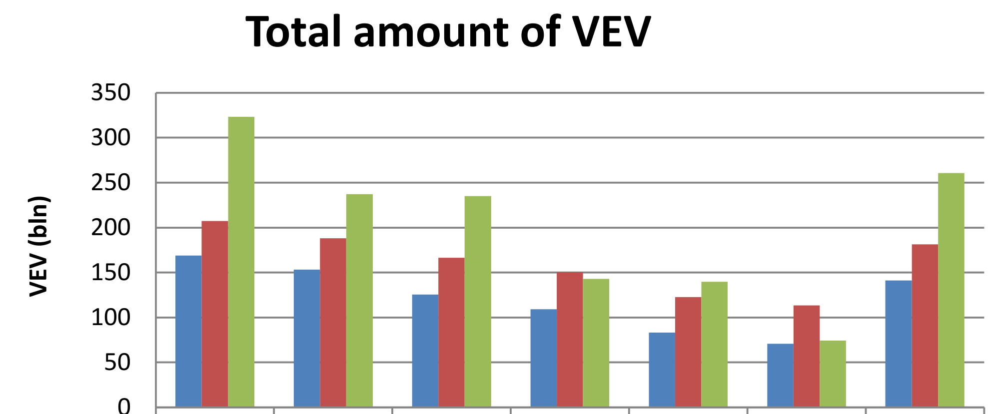
Amount of VEV in relation to the funding level
In Table 5.2 the amount of VEV and the related VEV levels per pension fund is shown. These levels can be compared with the VEV levels of pension funds in the Netherlands, which are shown in appendix C. The percentages of the VEV levels give an indication about the percentage of required equity in relation to the total liabilities of pension funds. The percentage of total liabilities is 100% and the VEV buffer is the additional percentage on top in the columns for VEV levels.

Pension fund	Total VEV current DNB model (in billions)	VEV level (%)	Total VEV DNB model 2015 (in billions)	VEV level (%)	Total VEV CreditMetrics VaR model (in billions)	VEV level (%)
1: High risk asset mix; 25% hedge ratio	179.5	119.0	215.9	122.9	328.9	134.8
2: High risk asset mix; 50% hedge ratio	165.0	117.5	197.8	120.9	244.9	125.9
3: Moderate risk asset mix; 50% hedge ratio	139.5	114.8	177.1	118.7	242.8	125.7
4: Moderate risk asset mix; 75% hedge ratio	125.1	113.2	162.4	117.2	155.4	116.4
5: Low risk asset mix; 75% hedge ratio	103.1	110.9	136.8	114.5	152.3	116.1
6: Low risk asset mix; 100% hedge ratio	93.2	109.9	128.6	113.6	96.0	110.2
7: Average Dutch pension fund; 40% hedge ratio	153.7	116.3	191.3	120.2	267.8	128.3

Table 5.2: The total amount of VEV and VEV level per pension fund

As can be seen in Table 5.2 the percentage of VEV as a result of the current DNB model is between 9.9% and 19%, for the DNB model in 2015 the percentage is between 13.6% and 22.9% and the 97.5% VaR model has values between 10.2% and 34.8%. This is in line with the VEV levels of real pension funds in the Netherlands. In appendix C the lowest percentage of VEV is 8% and the highest percentage is 30%.

Total amount of VEV per pension fund
The percentage of VEV that is added to the current DNB model in 2015 is about 4% for all pension funds. This means that pension funds should increase their buffers to reach these new percentages of VEV funding levels. As can be seen the percentages of VEV for the VaR model are different than the DNB models for high risk pension funds. For low risk pension funds the difference between the DNB models and the VaR model is small. Interest risk has a high influence on the amount of VEV, which can be seen by looking at the interest hedge ratios of the different pension funds. Pension funds with high hedge ratios have a significantly lower total result of the VEV. Because of the relatively low values for interest rate risk for the low risk pension funds, the difference of VEV between the DNB models and the VaR model becomes smaller. Further explanation for the differences between models will follow in paragraph 5.2 were the VEV results of individual risk factors is presented.



	1: High risk 25% hedge	2: High risk 50% hedge	3: Moderate risk 50% hedge	4: Moderate risk 75% hedge	5: Low risk 75% hedge	6: Low risk 100% hedge	7: Average pension fund 40% hedge
DNB model	168,9	153,4	125,6	109,3	83,3	70,7	141,2
DNB model 2015	207,2	188,2	166,3	150,6	122,6	113,3	181,4
97.5% VaR model	323,2	237,2	235,1	143	139,6	74,3	260,8

Figure 5.1: Total amount of VEV for DNB models and VaR model per pension fund

In figure 5.1 a graph of the total amount of VEV per pension fund is shown. The amount of VEV for actuarial risk in the DNB models is considered to be zero to be able to compare with the VaR model, where VEV for actuarial risk is not taken into account. This explains why the VEV values of figure 5.1 are a fraction lower than the VEV values in Table 5.2.

Comparison models with simulated losses
The VEV outcomes of the average pension fund in the Netherlands are compared with the outcomes of the simulated losses in Table 5.3. Based on this comparison the DNB models are rejected by the conditional coverage test. This means that based on the historical period between the years 1997-2013 the number of exceptions relating to the DNB models is too high. This can be explained by the high number of simulated losses beyond the VaR level in the years 2008 till 2013.

25 worst historical simulated losses average pension fund NL				Kupiec's test (T=5.024[49])	CC test (T=7.38 [50])	Basel traffic light approach
# of exceptions	Date	Simulated losses (x1000)	VaR level models	Test value	Test value	N=415
1	20081010	-753,397,039		14.29		0.0003
2	20081205	-410,200,561		10.34		0.0019
3	20081121	-400,060,668		7.44		0.0073
4	20100507	-398,228,572		5.23		0.0217
5	20110715	-311,108,046		3.52		0.0521
6	20100827	-283,007,347		2.23		0.1052
7	20110812	-280,606,306		1.27		0.1849
8	20120601	-275,139,954		0.60		0.2891
9	20100813	-268,059,329	97.5% VaR	0.20		0.4099
10	20111216	-257,673,689		0.01		0.5356
11	19991105	-256,704,439		0.04		0.6544
12	20120518	-252,641,292		0.25		0.7569
13	20110923	-252,554,257		0.63		0.8383
14	20090227	-246,888,213		1.17		0.8983
15	20011102	-245,461,715		1.86		0.9394
16	20081024	-238,436,943		2.69		0.9658
17	19980116	-202,335,771		3.65		0.9816
18	20030124	-199,657,582	DNB 2015	4.73	12.68	0.9906
19	20110909	-178,950,819		5.93		0.9954
20	19971219	-164,957,667		7.23		0.9979
21	20060526	-148,467,940		8.65		0.9991
22	19981204	-145,305,901		10.16		0.9996
23	20040305	-143,161,361	DNB	11.77	19.38	0.9998
24	20090130	-141,081,967		13.47		0.9999
25	20050610	-132,216,027		15.26		1.0000

Table 5.3: The worst 25 yearly simulated losses based on historical 10-day returns between years 1997-2013

As can be seen in Table 5.3 the DNB model that will be implemented in 2015 is on the border of acceptation. In Kupiec's test the number of exceptions is 18 and the related test value is 4.73, which is lower than the 5.024 critical value, therefore the model is not rejected by this test. However because some exceptions are clustered the test value of the conditional coverage test is 12.68, which is too high for the model to be accepted by the conditional coverage test (critical value=7.38) and therefore the model is rejected by this test.

Figure 5.2 shows when the simulated yearly profits/losses go through the boundaries of the DNB models and the 97.5% VaR model. As can be seen in the year 2008 a lot of exceptions occur. The three worst simulated losses all happened within this year. Because of the years of crisis a large number of exceptions is expected and the value of VEV based on the VaR model is relatively high compared with the DNB models.

[49] Critical value based on the chi-square distribution with one degree of freedom for a confidence interval of 97.5%
[50] Critical value based on a chi-square distribution with two degrees of freedom for a confidence interval of 97.5%

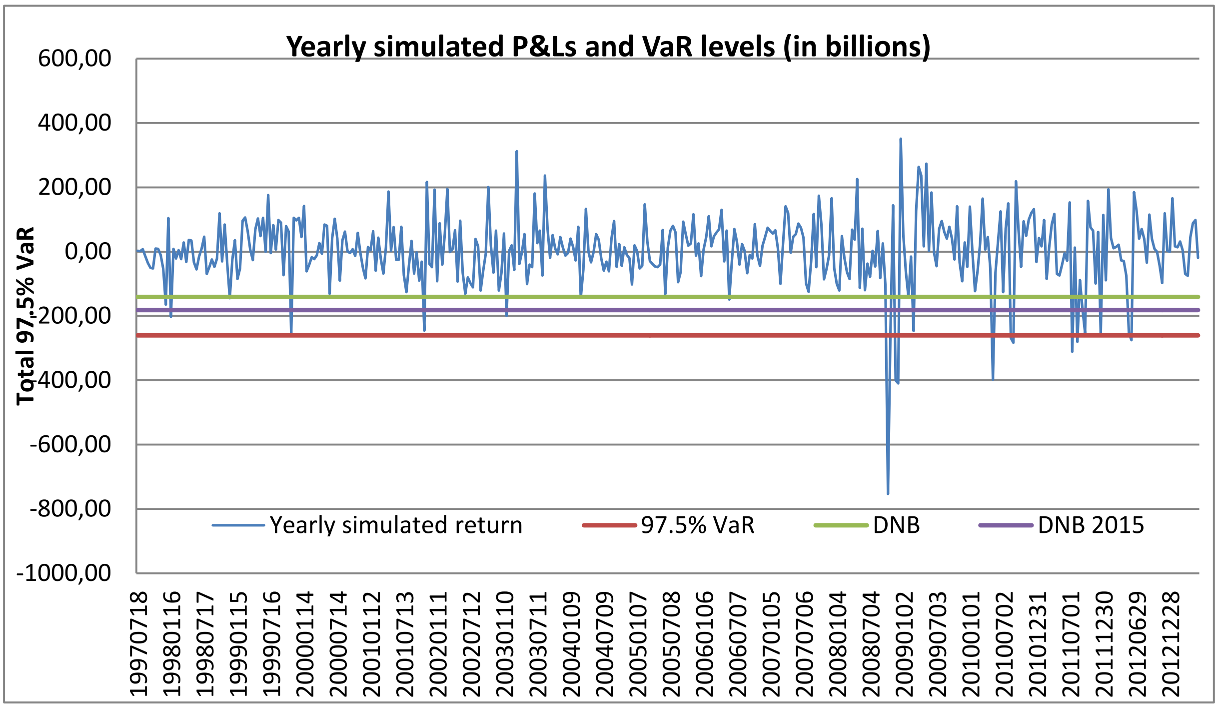


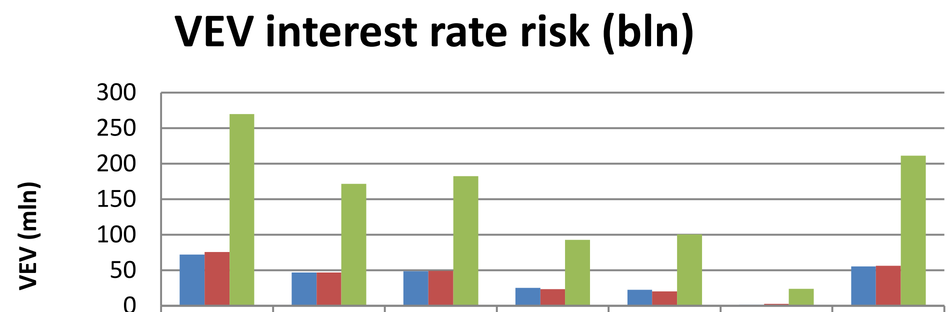
Figure 5.2: Yearly simulated profits and losses and solvency buffers DNB models and VaR model

5.2 Comparing individual risk factor VaRs and correlations between risk factors

In this paragraph the individual values of VEV per risk factor as result of the current DNB model and the DNB model in 2015 are compared with the 97.5% historical VaRs per risk factor calculated in RiskMetrics. If the individual VaRs in this paragraph based on a historical period between the years 1997-2013 are significantly different from the outcomes of the DNB model, the DNB method of calculation might not give a good estimation of the risk related to this risk factor. That is if the VaR model is a correct model, which will be tested in chapter 6 where the results per risk factor of DNB model and historical VaR model are back-tested against historical benchmarks.

5.2.1 Interest rate risk buffer (S1)

The amount of VEV for of interest rate risk for all models is shown in figure 5.3. The amount of VEV as result of the 97.5% VaR model is significantly higher than the amount needed by the DNB models. This can be explained by the high volatility of the euro swap curve in the years 1997-2013. Large changes of the interest rate curve have led to high losses in the historical VaR model. The yearly simulated losses in the 97.5% VaR model are based on 10-day returns of the euro swap rates. These 10-day returns show high volatility, which led to large simulated losses in the tail of the distribution of returns; this is why the VEV levels related to the 97.5% VaR model are high. The amount of interest rate risk in the DND models is based on predetermined parameters as described in paragraph 2.3. These parameters are estimated based on historical information before 2005. In this historical period the returns of the interest rates were normally distributed. This explains why the amount for interest rate risk for these models is smaller compared with the VaR model.



	1: High risk 25%	2: High risk 50%	3: Moderate risk 50%	4: Moderate risk 75%	5: Low risk 75%	6: Low risk 100%	7: Average fund 40%
DNB model	72	46,6	48,4	25,3	22,5	1,4	55,3
DNB model 2015	75,4	46,6	48,8	23,2	20,2	2,5	56,3
VaR model	269,5	171,4	182,2	92,5	100,1	23,8	211,3

Figure 5.3: The amount of VEV for interest rate risk per pension fund

25 worst historical simulated losses for interest risk for average pension fund NL				Kupiec's test (T=5.024)	Basel traffic light approach
# of exceptions	date	Simulated losses (x1000)	Model	Test value	N=415
1	20081205	-620,110,862		14.29	0.0003
2	20081010	-366,858,292		10.34	0.0019
3	19991105	-327,966,251		7.44	0.0073
4	20100827	-273,930,188		5.23	0.0217
5	20011102	-266,045,983		3.52	0.0521
6	20110715	-257,707,974		2.23	0.1052
7	20120601	-255,927,704		1.27	0.1849
8	20100813	-224,620,140		0.60	0.2891
9	20011005	-224,614,468		0.20	0.4099
10	20100507	-217,824,075	97.5% VaR	0.01	0.5356
11	20111216	-201,539,645		0.04	0.6544
12	20081121	-180,650,165		0.25	0.7569
13	20110909	-178,586,053		0.63	0.8383
14	20040305	-177,117,553		1.17	0.8983
15	20081024	-172,978,037		1.86	0.9394
16	19980116	-168,372,522		2.69	0.9658
17	20050610	-157,819,892		3.65	0.9816
18	20110923	-155,758,664		4.73	0.9906
19	20030124	-154,019,944		5.93	0.9954
20	20120518	-146,877,833		7.23	0.9979
21	20120113	-139,424,836		8.65	0.9991
22	20110812	-138,109,677		10.16	0.9996
23	20080509	-137,532,535		11.77	0.9998
24	20030516	-136,994,872		13.47	0.9999
25	19971219	-129,404,085		15.26	1.0000
88		-56,000,000	DNB 2015	>15.26	1.0000
88		-55,300,000	DNB	>15.27	1.0000

Table 5.4: The 25 worst simulated losses for interest risk of the average pension fund in the Netherlands

Comparison models with simulated losses
Table 5.4 shows the 25 worst simulated yearly losses for interest risk of the average pension fund in the Netherlands. The levels of VEV for the DNB models relate to a large number of exceptions of simulated losses. In the years 2008-2013 there are 87 losses that are worse than the VEV levels relating to the DNB models, while the number of exceptions of the VaR model is ten. Based on this historical period the VEV values for interest rate risk are rejected by both Kupiec's as well as the conditional coverage test. The interest factors of the DNB models will be back-tested using the historical movements of the euro swap curve in chapter 6 to see if this leads to the same results as the model comparison done in this paragraph. Based on this results one would expect that the risk factors of the DNB model underestimate the risk related to movements of the euro swap curve.

Sensitivity analyses interest rate risk
Because the high levels of VEV in the VaR model for interest risk in this section an extra scenario analyses is performed. The sensitivity of the value of a portfolio to interest rate risk is tested by a parallel shift of the interest rate curve with a number of basis points. In Table 5.5 shows the influence of a number of parallel shifts on the funding levels of the different pension funds. As can be seen changing the interest curve with -10 basis points has just a small influence on the funding levels. The funding level of the average pension fund decreases from 96.7%, which is the current funding level to 95.6 with the adjusted curve. If the interest rates decrease with 1% the funding level of the average pension fund drops with 9.9%. With a decrease of the interest rate curve with 2% the funding level declines with 18.8%. However a decrease of 2% of an interest curve in a period of one year is not likely to happen, especially with the current interest rates, which are very low.

	Funding levels								
Parallel shift interest curve	+200bps	+100bps	+50bps	+10bps	0	-10bps	-50bps	-100bps	-200bps
Average pension fund	118.2%	107.1%	101.8%	97.7%	96.7%	95.6%	91.7%	86.8%	77.9%
High risk 25%	124.7%	110.3%	103.3%	98.0%	96.7%	95.3%	90.2%	84.0%	72.7%
High risk 50%	114.3%	105.2%	100.9%	97.5%	96.7%	95.8%	92.6%	88.7%	81.5%
Moderate risk 50%	114.8%	105.5%	101.0%	97.5%	96.7%	95.8%	92.4%	88.2%	80.5%
Moderate risk 75%	104.5%	100.5%	98.6%	97.0%	96.7%	96.3%	94.8%	92.9%	89.3%
Low risk 75%	104.4%	100.5%	98.6%	97.0%	96.7%	96.3%	94.7%	92.7%	88.9%
Low risk 100%	94.0%	95.5%	96.1%	96.6%	96.7%	96.8%	97.1%	97.4%	97.7%

Table 5.5: The results of parallel shifts on the funding levels of different pension funds

As can be seen in figure 5.4 the gap between assets and liabilities increases for larger parallel shifts. With decreases of the interest curve the present value of liabilities increases more than the present value of assets. The higher the hedge ratio of a pension fund, the smaller the gap between assets and liabilities.

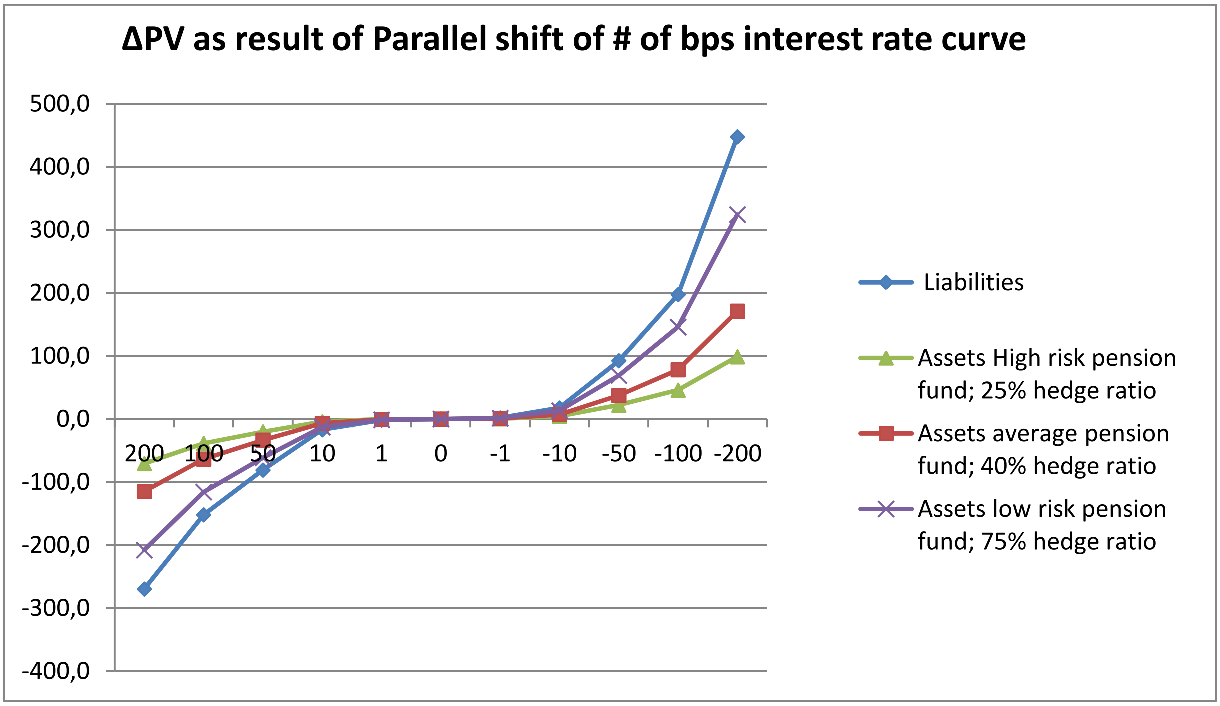


Figure 5.4: The △PV (in billions) of assets and liabilities for different pension funds as a result of parallel shifts

5.2.2 Equity risk buffer (S2) and amounts of VEV per asset type category and correlations between asset types

In this paragraph the results of the VEV amount for equity risk and the amounts per equity type are given. Furthermore correlations between equity types are tested to see if the DNB correlations correspond with the real correlations between equity types based on the historical look-back period used for the historical VaR model.

Comparison VEV for total equity risk of models with simulated losses

As can be seen in Table 5.6 the amount of VEV for equity risk in the current DNB model is not rejected by the conditional coverage test. The test value is 0.6, which is lower than the 7.38 critical value. In the DNB model that will be implemented in 2015 the amount of VEV leads to a lower number of exceptions than the current DNB model. As a result the model in 2015 has a higher test value of the conditional coverage test (3.52). Based on this information you can argue that the current DNB model gives a good representation of the amount of equity needed and the adjustments in 2015 seem to overestimate the amount of equity risk compared with the 97.5% VaR model. The lower values of VEV in the VaR model can be caused by two reasons. The first reason is that the positions of the VaR model have lower volatility then the expected volatility in the DNB model. The second reason is that the historical VaR method takes also into account real correlations between positions, while the DNB model only calculates correlations between equity types. As described in paragraph 2.4 the total amount of VEV for equity risk in the DNB models is based on an aggregation of four types of equity; equity mature markets, equity emerging markets, private equity and real estate. The correlations between these equity types are 0.75 in the DNB model. The real correlations between equity types of the VaR model will be shown later on in this paragraph.

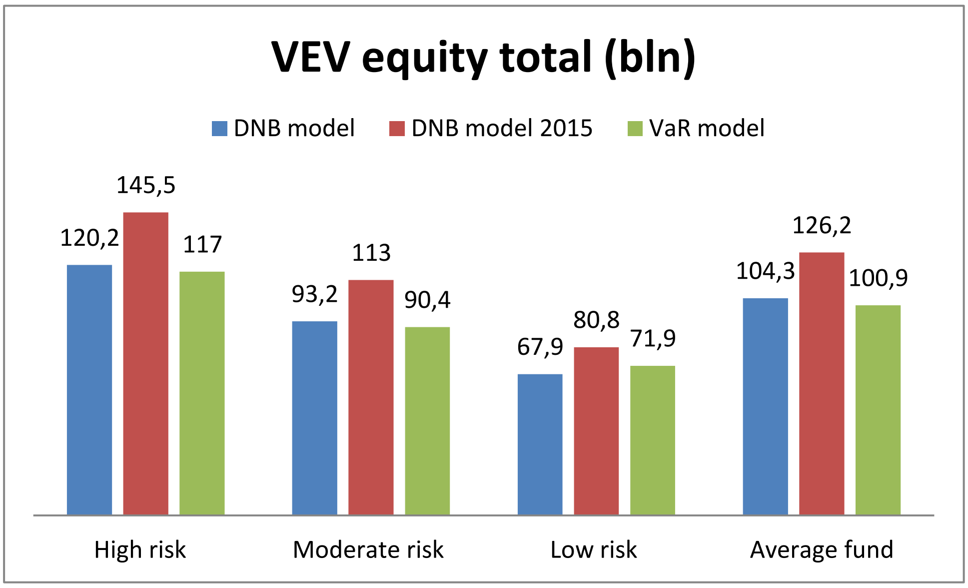


Figure 5.5: VEV equity total per pension fund

25 worst historical simulated losses for total equity of average pension fund NL				Kupiec's test (T=5.024)	CC-test (T=7.38)	Basel traffic light approach	
# of exceptions	Date	Simulated losses (x1000)	VaR levels models	Test value	Test value	# of exceptions	N=415
1	20081010	-286,512,076		14.29		1	0.0003
2	20081121	-208,333,862		10.34		2	0.0019
3	20100507	-140,133,147		7.44		3	0.0073
4	20110812	-139,094,516		5.23		4	0.0217
5	20090227	-133,202,268	DNB 2015	3.52	3.52	5	0.0521
6	20090116	-108,821,491		2.23		6	0.1052
7	20100702	-107,098,930		1.27		7	0.1849
8	20080704	-105,229,347	DNB	0.60	0.60	8	0.2891
9	20010921	-102,446,983	97.5%VaR	0.20		9	0.4099
10	20080118	-99,928,184		0.01		10	0.5356
11	20070803	-91,755,268		0.04		11	0.6544
12	20120518	-90,041,988		0.25		12	0.7569
13	20080620	-85,264,934		0.63		13	0.8383
14	20080926	-83,261,147		1.17		14	0.8983
15	20100129	-78,816,839		1.86		15	0.9394
16	20080314	-74,583,738		2.69		16	0.9658
17	20110923	-72,952,837		3.65		17	0.9816
18	20111118	-71,726,570		4.73		18	0.9906
19	20020726	-71,549,629		5.93		19	0.9954
20	20071221	-71,360,174		7.23		20	0.9979
21	20071109	-70,296,696		8.65		21	0.9991
22	20070817	-66,399,970		10.16		22	0.9996
23	20121116	-59,622,651		11.77		23	0.9998
24	20060609	-58,971,480		13.47		24	0.9999
25	20130531	-56,604,379		15.26		25	1.0000

Table 5.6: The 25 worst simulated losses for total equity of the average pension fund in the Netherlands

Comparison VEV equity mature markets with simulated losses

In Table 5.7 the results of the simulated losses for equity mature markets are shown. The current DNB model has a test value of 0.6 and is therefore not rejected by Kupiec's test. The number of exceptions in the DNB model in 2015 lead to a test value of 7.44, which is higher than the critical value, therefore this model is rejected by Kupiec's test. Given the low number of exceptions, this model tends to overestimate risk for equity mature markets. It can be the case that the overestimation of equity risk is due to the fact that the positions on which the 97.5% VaR model is based have relatively low volatility even in the years of crisis after 2008. The models are back-tested against the MSCI world index in chapter 6. The results of these back-tests will show if the positions of the average pension fund in the Netherlands represent the risk related to movements of mature markets in the world.

25 worst historical simulated losses of mature market equity of average pension fund NL				**Kupiec's test (T=5.024)**	**Basel traffic light approach**	
# of exceptions	Date	Simulated losses (x1000)	VaR levels models	Test value	# of exceptions	N=415
1	20011019	-176,170,155		14.29	1	0.0003
2	20010504	-128,335,965		10.34	2	0.0019
3	19970718	-89,530,121	DNB 2015	7.44	3	0.0073
4	20120629	-82,531,001		5.23	4	0.0217
5	19980703	-79,605,631		3.52	5	0.0521
6	20041112	-76,104,726		2.23	6	0.1052
7	20100326	-73,452,192		1.27	7	0.1849
8	20090925	-67,864,232	97.5% VaR; DNB	0.60	8	0.2891
9	20120309	-65,874,173		0.20	9	0.4099
10	20030502	-65,171,269		0.01	10	0.5356
11	19990129	-61,388,797		0.04	11	0.6544
12	20041029	-58,315,570		0.25	12	0.7569
13	19981120	-56,555,614		0.63	13	0.8383
14	20010126	-53,046,551		1.17	14	0.8983
15	19990910	-49,706,895		1.86	15	0.9394
16	20111230	-48,655,720		2.69	16	0.9658
17	20120907	-47,627,662		3.65	17	0.9816
18	19981106	-44,487,940		4.73	18	0.9906
19	20040528	-44,278,495		5.93	19	0.9954
20	20000714	-42,737,244		7.23	20	0.9979
21	20070202	-42,069,404		8.65	21	0.9991
22	19980522	-41,830,904		10.16	22	0.9996
23	20051111	-39,628,793		11.77	23	0.9998
24	20100115	-38,944,699		13.47	24	0.9999
25	20030321	-38,622,344		15.26	25	1.0000

Table 5.7: The 25 worst simulated losses mature market equity of the average pension fund in the Netherlands

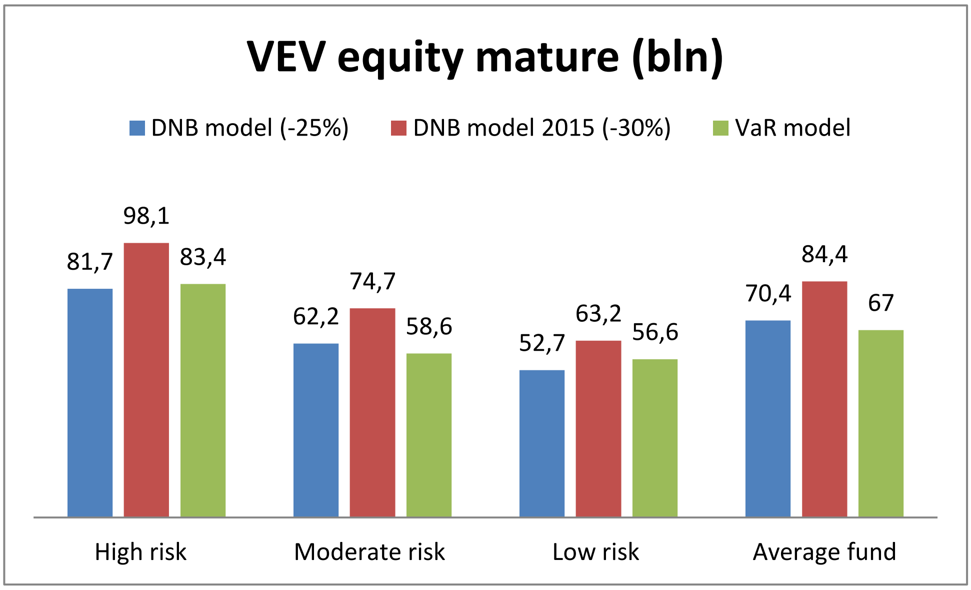


Figure 5.6: VEV equity mature markets per pension fund

Comparing VEV equity emerging markets with simulated losses

The amounts of VEV needed for equity emerging markets is tested in this section. As can be seen in Table 5.8 the results of the tests for equity emerging markets of all models are in the green region and therefore the null hypothesis is not rejected. As can be seen in Table 5.8 the current DNB model has a number of exceptions of 13, which is in the non rejection region of the VaR model. The number of exceptions of the DNB model in 2015 is relatively low, because this model has the highest value of VEV, but the model in 2015 is still not rejected by Kupiecs test. In chapter 6 the results of the DNB models are back-tested against the MSCI emerging market index, which is a benchmark for equity emerging markets. The results of these back-tests will show if the required extra buffer for emerging markets equity in 2015 is required.

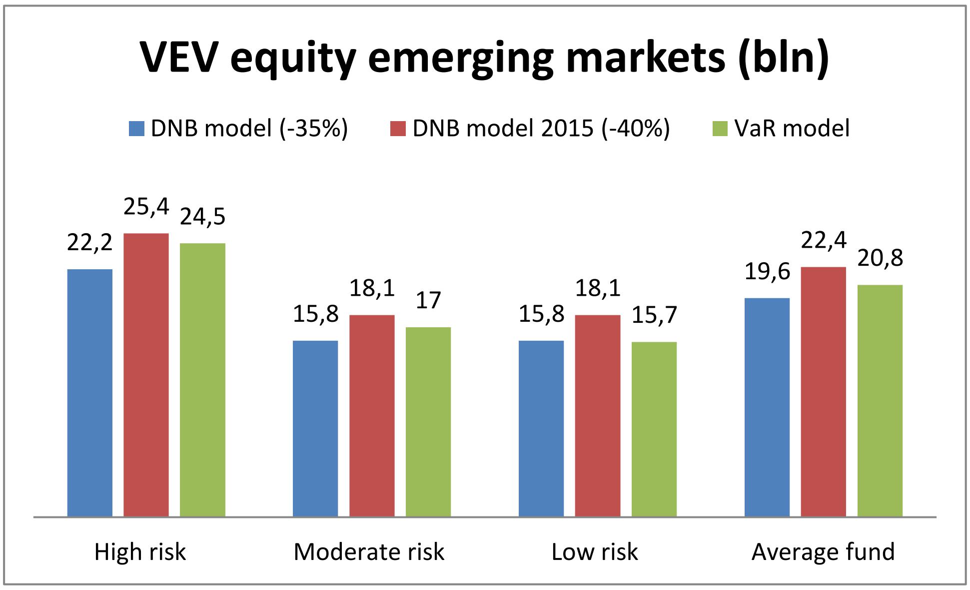


Figure 5.7: VEV equity emerging markets per pension fund

25 worst historical simulated losses of emerging markets equity of average pension fund NL				Kupiec's test (T=5.024)	Basel traffic light approach	
# of exceptions	Date	Simulated losses (x1000)	VaR levels models	Test value	# of exceptions	N=415
1	20081010	-44,166,242		14.29	1	0.0003
2	20081121	-29,368,390		10.34	2	0.0019
3	20080704	-25,176,295		7.44	3	0.0073
4	20071221	-24,470,128		5.23	4	0.0217
5	20110812	-23,695,696	DNB 2015	3.52	5	0.0521
6	20110923	-22,041,582		2.23	6	0.1052
7	20060526	-21,953,325		1.27	7	0.1849
8	20070817	-21,697,419		0.60	8	0.2891
9	20081024	-21,688,343		0.20	9	0.4099
10	20010921	-20,835,604		0.01	10	0.5356
11	20040430	-20,826,668	97.5% VaR	0.04	11	0.6544
12	20080912	-19,918,641		0.25	12	0.7569
13	20090227	-19,816,789	DNB	0.63	13	0.8383
14	20060609	-19,520,131		1.17	14	0.8983
15	20120518	-19,299,824		1.86	15	0.9394
16	20080118	-18,666,946		2.69	16	0.9658
17	20100507	-18,207,171		3.65	17	0.9816
18	20001229	-17,966,019		4.73	18	0.9906
19	20090116	-17,399,570		5.93	19	0.9954
20	20080314	-17,358,355		7.23	20	0.9979
21	20000922	-17,126,978		8.65	21	0.9991
22	20001201	-16,970,994		10.16	22	0.9996
23	20100129	-16,515,509		11.77	23	0.9998
24	20071123	-16,372,980		13.47	24	0.9999
25	20020726	-16,097,038		15.26	25	1.0000

Table 5.8: The 25 worst simulated losses emerging markets of the average pension fund in the Netherlands

Comparing VEV private equity and hedge funds with simulated losses

The amount of VEV for private equity and hedge funds for the VaR model for the average pension fund in the Netherlands is based on the historical returns of three hedge funds and two venture capital funds. Based on the historical simulated losses in Table 5.9 the DNB models have relatively high VEV levels and therefore a low number of exceptions. Based on this sample of funds in the VaR model the DNB model in 2015 is rejected by Kupiec's test but not rejected by the conditional coverage test. This because the conditional coverage test has a higher critical value and therefore the test value is not rejected. Based on the low number of exceptions the DNB models seem to overestimate the risk related to private equity and hedge funds. This conclusion is based on the assumption that the VaR model is correct; this is back-tested in chapter 6.

In figure 5.8 the amount of VEV for private equity and hedge funds per pension fund is shown. As can be seen the sample of the VaR model corresponds to a relatively low VaR value compared with the DNB model in 2015. This means that the positions in private equity and hedge funds in the VaR model had lower volatilities than the expected volatilities by the DNB model. To see if this sample is a good representation of the risk for private equity and hedge funds the models will be back-tested against a private equity index in chapter 6.

25 worst historical simulated losses of private equity of average pension fund NL				**Kupiec's test (T=5.024)**	**CC-test (T=7.38)**	**Basel traffic light approach**	
# of exceptions	Date	Simulated losses (x1000)	VaR levels models	Test value	Test value	# of exceptions	N=415
1	20081010	-52,982,920		14.29		1	0.0003
2	20081121	-41,025,885		10.34		2	0.0019
3	20110812	-28,684,563		7.44		3	0.0073
4	20100507	-27,648,581	DNB 2015	5.23	5.23	4	0.0217
5	20090227	-25,044,261		3.52		5	0.0521
6	20100702	-22,972,917	DNB	2.23	2.23	6	0.1052
7	20080704	-18,225,454		1.27		7	0.1849
8	20090116	-18,137,203		0.60		8	0.2891
9	20081024	-17,873,879		0.20		9	0.4099
10	20100129	-15,583,507	97.5% VaR	0.01		10	0.5356
11	20120518	-15,431,348		0.04		11	0.6544
12	20080314	-14,087,023		0.25		12	0.7569
13	20080926	-13,396,390		0.63		13	0.8383
14	20080912	-13,030,258		1.17		14	0.8983
15	20080118	-11,623,827		1.86		15	0.9394
16	20010921	-10,163,570		2.69		16	0.9658
17	20111118	-9,978,197		3.65		17	0.9816
18	20060526	-9,112,388		4.73		18	0.9906
19	20121116	-9,013,813		5.93		19	0.9954
20	20110923	-8,900,909		7.23		20	0.9979
21	20080620	-8,571,929		8.65		21	0.9991
22	20070803	-8,461,521		10.16		22	0.9996
23	20111216	-8,422,634		11.77		23	0.9998
24	20000421	-8,323,266		13.47		24	0.9999
25	20030307	-8,201,328		15.26		25	1.0000

Table 5.9: The 25 worst simulated losses private equity of the average pension fund in the Netherlands

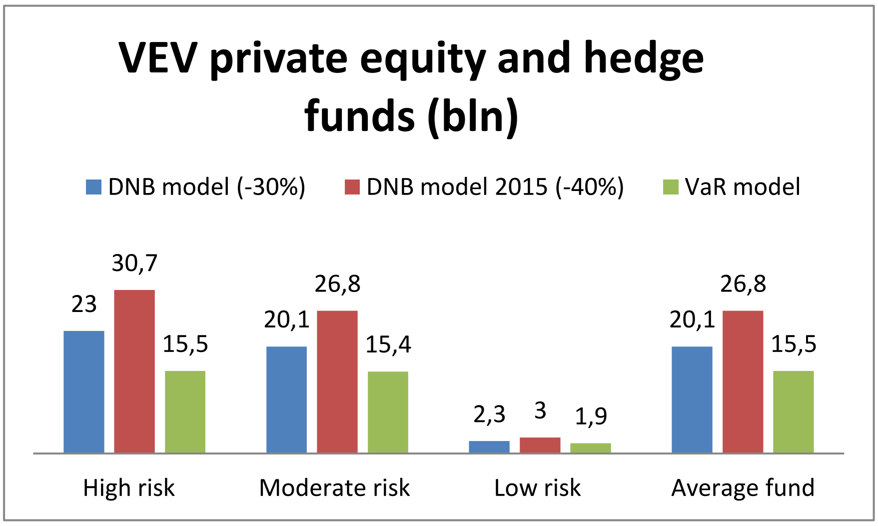


Figure 5.8: VEV private equity and hedge funds per pension fund

Comparing VEV real estate with simulated losses

The VEV for real estate of the VaR model is based on positions of three companies that do business in direct real estate. Table 5.10 shows the simulated losses of the VaR model for real estate. Based on this small sample of companies the test results of all models are in the non rejection region. Because the percentage of real estate in the asset mix is very small, real estate has a very small influence on total VEV for equity risk.

25 worst historical simulated losses of real estate of average pension fund NL				Kupiecs test (T=5.024)	Basel traffic light approach	
# of exceptions	Date	Simulated losses(x1000)	VaR levels models	Test value	# of exceptions	N=415
1	20081010	-3,750,489		14.29	1	0.0003
2	20110812	-2,936,076		10.34	2	0.0019
3	20060526	-2,903,602		7.44	3	0.0073
4	20100507	-2,608,435		5.23	4	0.0217
5	20081121	-2,502,091		3.52	5	0.0521
6	20110923	-2,251,891	DNB;DNB 2015	2.23	6	0.1052
7	20090227	-2,127,343		1.27	7	0.1849
8	20080118	-2,049,431		0.60	8	0.2891
9	20111118	-1,775,770	97.5% VaR	0.20	9	0.4099
10	20080704	-1,699,309		0.01	10	0.5356
11	20070302	-1,697,273		0.04	11	0.6544
12	20071221	-1,608,530		0.25	12	0.7569
13	20111216	-1,560,032		0.63	13	0.8383
14	20071109	-1,477,965		1.17	14	0.8983
15	20070803	-1,358,904		1.86	15	0.9394
16	20071123	-1,310,727		2.69	16	0.9658
17	20090313	-1,190,034		3.65	17	0.9816
18	20021227	-1,132,008		4.73	18	0.9906
19	20090522	-1,092,147		5.93	19	0.9954
20	20081024	-1,071,116		7.23	20	0.9979
21	20100702	-1,061,984		8.65	21	0.9991
22	20070706	-1,057,678		10.16	22	0.9996
23	20121116	-1,045,782		11.77	23	0.9998
24	20070608	-1,034,217		13.47	24	0.9999
25	20051028	-1,015,813		15.26	25	1.0000

Table 5.10: The 25 worst simulated returns real estate of the average pension fund in the Netherlands

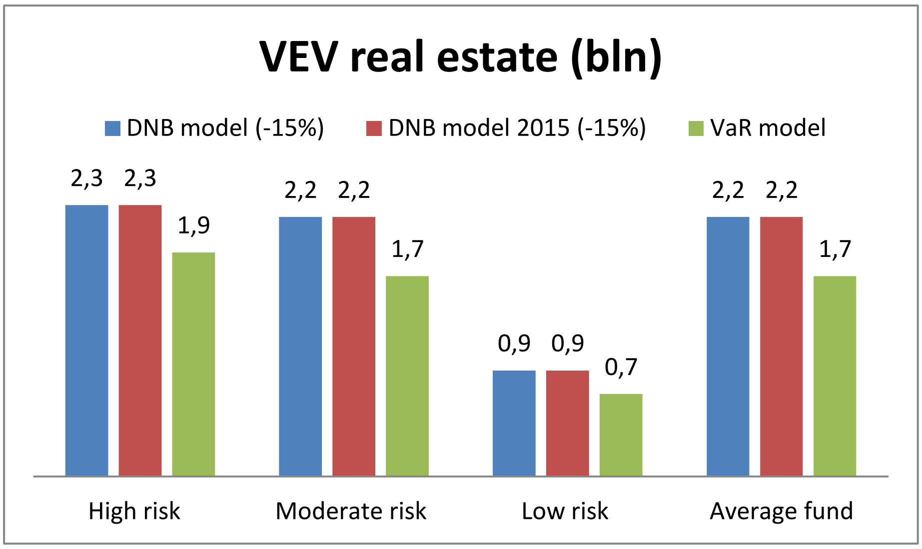


Figure 5.9: VEV real estate per pension fund

Testing correlations between equity types

In Table 5.11 the correlations between equity types of the different pension funds which are used for the 97.5% VaR model are shown. These correlations are based on years 1997-2013. In the DNB models the correlation between equity types is considered to be 0.75 for all combinations. The correlations between equity mature markets, equity emerging markets and private equity all are close to the value of 0.75. The correlations between real estate and the other equity types are significantly lower than 0.75. The low risk pension fund shows smaller correlations then the other pension funds; this is caused by the lower percentage of equity in the asset mix compared to other pension funds.

Correlations 1997-2013	Equity Mature-Equity Emerging	Equity Mature-Private equity	Equity Mature-Real estate	Equity Emerging-Private equity	Equity Emerging-Real estate	Private Equity-Real estate
Average pension fund	0.79	0.84	0.54	0.73	0.39	0.5
High risk	0.74	0.84	0.49	0.75	0.43	0.46
Moderate risk	0.75	0.85	0.5	0.73	0.43	0.46
Low risk	0.74	0.7	0.42	0.64	0.38	0.36

Table 5.11 Correlations between equity types years 1997-2013 for different pension funds

In the years before the financial crisis in 2008 the correlations between equity types are lower than correlations based on period 1997-2013.This can be seen in Table 5.12 were correlations between equity types in the years 1997-2007 are shown. Especially the correlations between direct real estate and the other equity types are significantly lower than the correlations of the historical period of the VaR model. In times of crisis, years 2008-2013 which are incorporated in the VaR model, correlations become higher, which leads to a higher value of VEV.

Correlations 1997-2007	Equity Mature-Equity Emerging	Equity Mature-Private equity	Equity Mature-Real estate	Equity Emerging-Private equity	Equity Emerging-Real estate	Private Equity-Real estate
Average pension fund	0.7	0.74	0.26	0.74	0.22	0.13
High risk	0.71	0.75	0.24	0.75	0.23	0.13
Moderate risk	0.7	0.75	0.25	0.72	0.22	0.13
Low risk	0.67	0.51	0.15	0.52	0.15	0.05

Table 5.12: Correlations between equity types years 1997-2007 for different pension funds

5.2.3 Currency risk buffer (S3)

The VEV buffer for currency risk in the current DNB model is significantly higher than the buffer for currency risk in the VaR model, as can be seen in figure 5.10. This is because the current model calculates currency risk using a -20% shock for assets in foreign currencies, which in comparison with the VaR model overestimates currency risk. The value of VEV for the DNB model in 2015 is lower but there is still a large difference with the VaR model. The low value for currency risk in the VaR model can be explained by a well spread portfolio where downward movements of one currency are compensated with upward movements of other currencies. As many pension funds have a well spread portfolio with multiple foreign currencies, the diversification effect should be taken into account. This partly happens in the DNB model in 2015, where the shock for currency risk is adjusted to 15%. The exposure to foreign currencies of the average pension fund is back-tested against currency exchange rates in chapter 6. In chapter 6 there will be more information about the influence of the diversification effect of a well-spread portfolio of currencies versus movements of individual currencies.

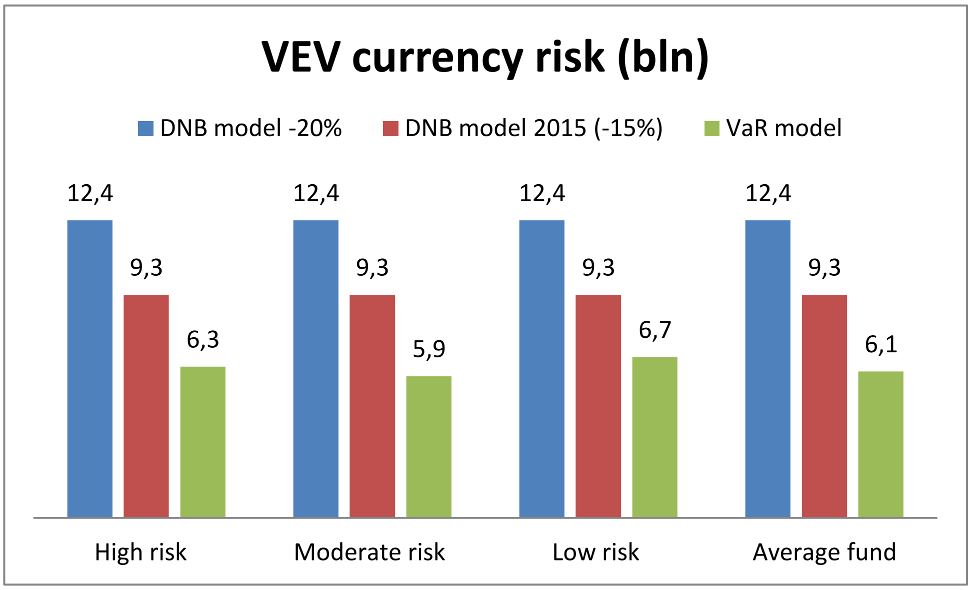


Figure 5.10: VEV for currency risk per pension fund

Comparing VEV currency risk with simulated losses

Table 5.13 shows the simulated returns for currency risk of the VaR model, the number of exceptions is zero for the current model and one for the model in 2015. This low number of exceptions leads to high test values in the Kupiec's test. Both DNB models have higher test values than the critical value of Kupiec's test and are rejected by this test. Based on this information the DNB models overestimate the risk related to movements of foreign currencies.

25 worst historical simulated losses currency risk of average pension fund NL				Kupiecs test (T=5.024)	Basel traffic light approach	
# of exceptions	Date	Simulated losses (x1000)	VaR levels models	Test value	# of exceptions	N=415
0			DNB	14.33	0	0.0000
1	20081219	-9,737,748	DNB 2015	14.29	1	0.0003
2	20000602	-8,936,480		10.34	2	0.0019
3	20100924	-7,950,894		7.44	3	0.0073
4	19971107	-7,922,279		5.23	4	0.0217
5	20001229	-7,895,851	97.5% VaR	3.52	5	0.0521
6	19990730	-5,723,510		2.23	6	0.1052
7	20020628	-5,604,304		1.27	7	0.1849
8	20030124	-5,422,144		0.60	8	0.2891
9	20080926	-5,306,845		0.20	9	0.4099
10	20001103	-5,254,107		0.01	10	0.5356
11	19980911	-5,105,128		0.04	11	0.6544
12	20021213	-4,593,703		0.25	12	0.7569
13	20040109	-4,483,670		0.63	13	0.8383
14	20120907	-4,478,645		1.17	14	0.8983
15	20010824	-4,433,251		1.86	15	0.9394
16	20020614	-4,422,340		2.69	16	0.9658
17	20020503	-4,347,394		3.65	17	0.9816
18	20060428	-4,331,870		4.73	18	0.9906
19	20101008	-4,312,112		5.93	19	0.9954
20	20111021	-4,160,241		7.23	20	0.9979
21	20000922	-4,068,542		8.65	21	0.9991
22	20030516	-3,959,441		10.16	22	0.9996
23	20030919	-3,892,819		11.77	23	0.9998
24	20080314	-3,858,718		13.47	24	0.9999
25	20001215	-3,852,533		15.26	25	1.0000

Table 5.13: The 25 worst simulated losses currency risk of the average pension fund in the Netherlands

5.2.4 Commodity risk buffer (S4)

The amount of VEV for commodity risk is a very small percentage of the total amount of VEV. This is because the weight of commodities in the asset mix is very small. As can be seen in Table 5.14 the number of exceptions based on the DNB models is very small. This means that the DNB model overestimates the amount of commodity risk based on the historical look-back period of the simulated losses. However the simulated losses in Table 5.14 are based on just a few positions of commodities, which represent the risk for commodities. Because it is just a small sample it is risky to draw any conclusions from this. In chapter 6 the shocks used in the DNB model are back-tested against the historical movements of the ACWI commodity producers' index, which is a benchmark for all positions in commodities.

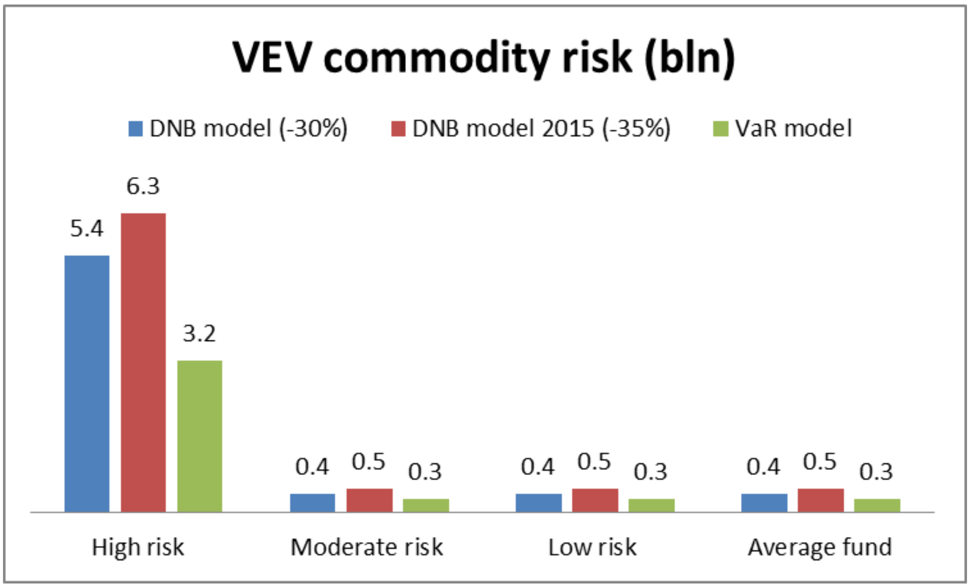


Figure 5.11: The amount of VEV for commodity risk for different pension funds

25 worst historical simulated losses of commodity risk of average pension fund NL				Kupiec's test (T=5.024)	Basel traffic light approach	
# of exceptions	Date	Simulated losses (x1000)	VaR levels models	Test value	# of exceptions	N=415
0			DNB 2015	14.33	0	0.0000
1	20081024	-493,413		14.29	1	0.0003
2	20080815	-444,078		10.34	2	0.0019
3	20110923	-443,798	DNB	7.44	3	0.0073
4	20081010	-413,834		5.23	4	0.0217
5	20030321	-366,379		3.52	5	0.0521
6	20080912	-336,744		2.23	6	0.1052
7	20081205	-335,358		1.27	7	0.1849
8	20111216	-324,748		0.60	8	0.2891
9	20060915	-313,484		0.20	9	0.4099
10	20041210	-296,452	97.5% VaR	0.01	10	0.5356
11	20130419	-276,480		0.04	11	0.6544
12	20080328	-271,609		0.25	12	0.7569
13	20060526	-261,939		0.63	13	0.8383
14	20060609	-254,167		1.17	14	0.8983
15	20100129	-250,007		1.86	15	0.9394
16	20010601	-246,897		2.69	16	0.9658
17	20090116	-221,697		3.65	17	0.9816
18	20080801	-207,907		4.73	18	0.9906
19	20060818	-207,279		5.93	19	0.9954
20	20110506	-202,873		7.23	20	0.9979
21	20130222	-196,025		8.65	21	0.9991
22	20060217	-195,559		10.16	22	0.9996
23	20130517	-193,268		11.77	23	0.9998
24	20101119	-192,355		13.47	24	0.9999
25	19971024	-186,773		15.26	25	1.0000

Table 5.14: The 25 worst simulated losses commodity risk of the average pension fund in the Netherlands

5.2.5 Comparing credit risk buffer (S5) with simulated losses

The current DNB model estimates credit risk by a relative increase of the credit spread of all positions with 40%. Looking at the historical simulated losses for credit risk in Table 5.15 this calculation of VEV leads to 27 exceptions and therefore the current DNB model is rejected. In 2015 the credit spread of assets per credit rating category is changed with an absolute number of basis points. This method of calculation leads to a relatively high amount of VEV for credit risk. This high VEV level leads to zero exceptions of simulated losses in the years 1997-2013. This means that this method overestimates credit risk based on this historical time period. In chapter 6 the absolute yearly shocks are back-tested against historical changes of option-adjusted credit spreads for different credit ratings.

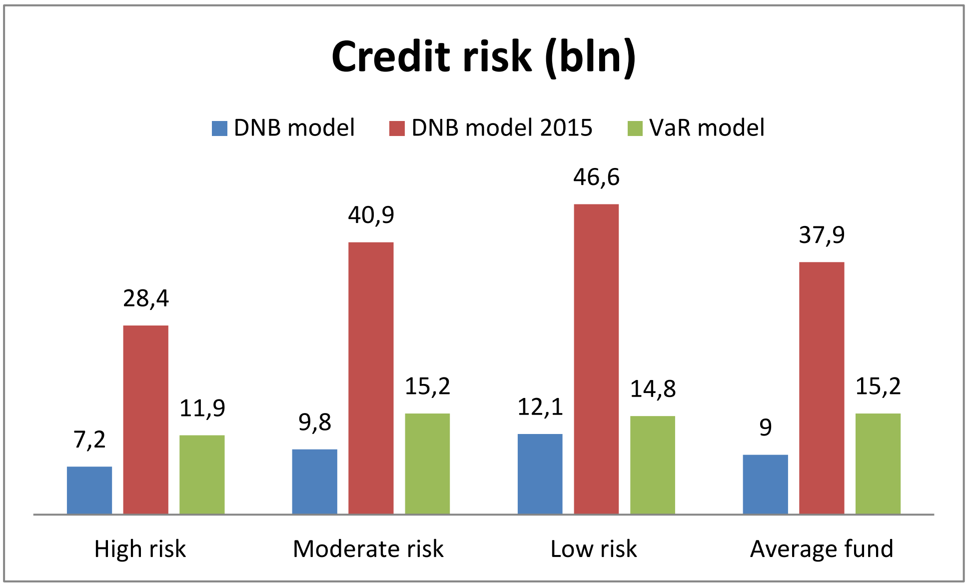


Figure 5.12: Amount of VEV for credit risk per pension fund

In figure 5.12 the credit risk per pension fund is shown. The amount for credit risk is higher for the low risk pension fund, because this fund has a higher percentage of fixed assets in its portfolio. Applying the same reasoning the amount of credit risk for the high risk portfolio is relatively low, because the low percentage of fixed assets in the asset mix. There is a huge difference between the amount of VEV based on the current DNB model and the DNB model in 2015, this is because of the different methods of calculation of credit risk. The back-tests in chapter 6 will show if the buffer for assets with different credit ratings that will be used in the DNB model of 2015 is required.

25 worst historical simulated losses credit risk of average pension fund NL				Kupiec's test (T=5.024)	Basel traffic light approach	
# of exceptions	Date	Simulated losses (x1000)	VaR levels models	Test value	# of exceptions	N=415
0			DNB 2015	14.33	0	0.0000
1	20110715	-32,786,576		14.29	1	0.0003
2	20081024	-27,980,678		10.34	2	0.0019
3	20111118	-23,078,706		7.44	3	0.0073
4	20090116	-20,151,263		5.23	4	0.0217
5	20111021	-19,836,113		3.52	5	0.0521
6	20110923	-18,966,876		2.23	6	0.1052
7	20100507	-18,874,961		1.27	7	0.1849
8	20090227	-18,077,089		0.60	8	0.2891
9	20081205	-17,314,296		0.20	9	0.4099
10	20090130	-16,401,761	97.5% VaR	0.01	10	0.5356
11	20100604	-13,472,737		0.04	11	0.6544
12	20100813	-13,416,762		0.25	12	0.7569
13	20081010	-13,385,584		0.63	13	0.8383
14	19980116	-12,347,915		1.17	14	0.8983
15	20120113	-11,649,020		1.86	15	0.9394
16	19991105	-11,211,848		2.69	16	0.9658
17	20100423	-10,874,198		3.65	17	0.9816
18	20130208	-10,601,667		4.73	18	0.9906
19	20110909	-10,161,379		5.93	19	0.9954
20	19971219	-10,101,561		7.23	20	0.9979
21	20120420	-10,095,140		8.65	21	0.9991
22	19981023	-9,926,418		10.16	22	0.9996
23	20130531	-9,643,851		11.77	23	0.9998
24	20000602	-9,639,386		13.47	24	0.9999
25	20120518	-9,054,023		15.26	25	1.0000
27			DNB	>15.26	27	1.0000

Table 5.15: The 25 worst simulated losses credit risk of the average pension fund in the Netherlands

5.2.6 Actuarial risk buffer (S6)

The buffer for actuarial risk of the average pension fund in the Netherlands in the DNB models is 60.8bln. This value is based on the old age pension rule with survivors' pension. In the comparison of the models the value for actuarial risk is considered to be zero, because the VaR model does not include actuarial risk.

5.2.7 Buffer active investment risk (S7)

The buffers for active investment risk in the DNB model in 2015 which are shown in figure 5.13 are based on Table 4.5 where the tracking errors for low risk, moderate risk and high risk pension funds are given. The value for active investment risk is based on the multiplication of the tracking error with an adjustment for investment costs and the weight of equity in the asset mix. This is an approximation of active investment risk. The high value of VEV for the high risk pension fund in figure 5.13 can be explained by the high percentage of equity in the asset mix and the high tracking error used for high risk pension funds in Table 4.5. The amount of VEV for active investment risk grows exponentially when both the weight of equity in the asset mix as well as the tracking error increases.

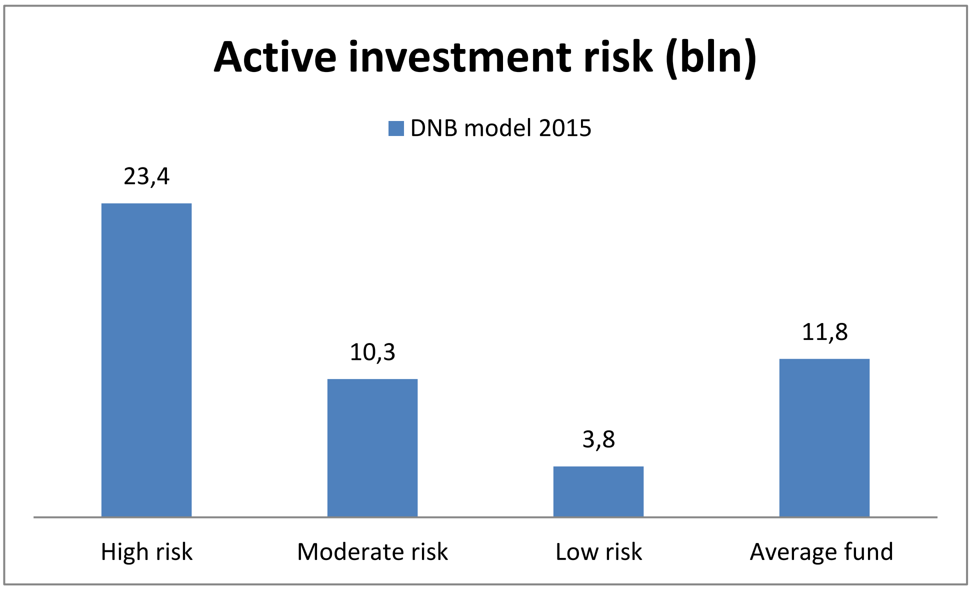


Figure 5.13: Amount of active investment risk per pension fund

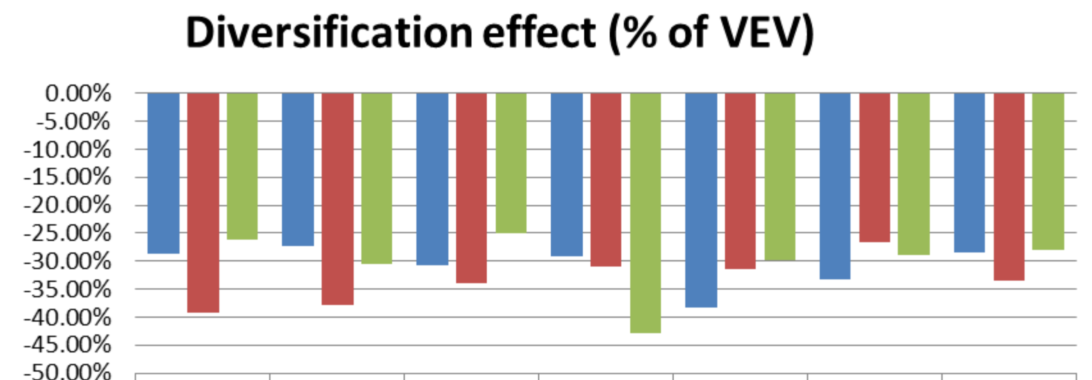
	1: High risk 25%	2: High risk 50%	3: Moderate risk 50%	4: Moderate risk 75%	5: Low risk 75%	6: Low risk 100%	7: Average fund 40%
% S7 of total VEV	10.8%	11.8%	5.8%	6.3%	2.8%	3.0%	6.2%

Table 5.16: Percentage active investment risk (S7) of total VEV per pension fund

In Table 5.16 the percentages of active investment risk in relation to the total amount of VEV are shown. Pension funds with the same asset mix but higher hedge ratios have a higher percentage of VEV for active investment risk. This is because the total amount of VEV for these pension funds is smaller and therefore the relative percentage of active investment risk is higher.

5.2.8 Diversification advantage

When all risk factors are aggregated a diversification advantage occurs. When correlations between risk types are zero or even negative the diversification effect is higher than when positive correlations are taken into account. The diversification effect per pension fund as percentage of total VEV is shown in figure 5.14. Comparing the diversification effects of the current DNB model with the DNB model in 2015, the diversification advantage is higher for the model in 2015 for every pension fund except for the low risk pension funds. The higher diversification effect can be explained by the lower correlation between interest risk and equity risk in 2015, which are the risk factors which contribute the most to the total amount of VEV in the DNB model. The VaR model takes into account real correlations between positions with explains the relatively low diversification advantage for most pension funds.



	1: High risk	2: High risk	3: Moderate risk	4: Moderate risk	5: Low risk	6: Low risk	7: Average fund
DNB model	-28.60%	-27.31%	-30.73%	-29.19%	-38.42%	-33.24%	-28.47%
DNB model 2015	-39.14%	-37.89%	-33.97%	-31.01%	-31.48%	-26.74%	-33.41%
VaR model	-26.21%	-30.61%	-25.05%	-42.87%	-29.75%	-28.93%	-27.99%

DNB model   DNB model 2015   VaR model

Figure 5.14: The diversification effect for different pension funds

In Table 5.17 the correlations between risk types in the years 1997-2013 are shown. The current DNB model uses a correlation of 0.65 between interest rate risk and equity risk and a correlation of zero between other risk factors. In Table 5.17 the correlation between IR market risk (interest rate risk) and equity risk is 0.32 which is significantly lower than the correlation in the DNB model. In the model in 2015 the correlation between interest rate risk and equity risk is adjusted to 0.4 and correlations of 0.5 between interest rate risk and credit risk and equity risk and credit risk are added. The correlation between interest rate risk and credit risk is 0.41 and the correlation between equity risk and credit risk is 0.51 based on years 1997-2013. These correlations are both close to the 0.5 used in the DNB model in 2015.

	Total	Commodity Risk	Equity Risk	FX Risk	IR Market Risk	Issuer Specific Risk
Total	1.00	0.22	0.73	-0.18	0.88	0.60
Commodity Risk	0.22	1.00	0.28	-0.32	0.12	0.09
Equity Risk	0.73	0.28	1.00	-0.13	0.32	0.51
FX Risk	-0.18	-0.32	-0.13	1.00	-0.17	-0.30
IR Market Risk	0.88	0.12	0.32	-0.17	1.00	0.41
Issuer Specific Risk	0.60	0.09	0.51	-0.30	0.41	1.00

Table 5.17: Matrix of correlations between risk types years 1997-2013

	Total	Commodity Risk	Equity Risk	FX Risk	IR Market Risk	Issuer Specific Risk
Total	1	0.14	0.64	0.25	0.87	0.64
Commodity Risk	0.14	1	0.18	-0.23	0.07	0.12
Equity Risk	0.64	0.18	1	0.2	0.18	0.23
FX Risk	0.25	-0.23	0.2	1	0.13	0.11
IR Market Risk	0.87	0.07	0.18	0.13	1	0.64
Issuer Specific Risk	0.64	0.12	0.23	0.11	0.64	1

Table 5.18: Matrix of correlations between risk types years 1997-2007

In Table 5.18 the correlations between risk types in times before crisis (years 1997-2007) are shown. Comparing these correlations with the correlations in Table 5.17 it can be seen that correlations are higher in times of economic recession, except for the correlations between foreign exchange (FX) risk and the other asset types which are negative based on years 1997-2013 and are slightly positive in years 1997-2007. This means that calculating a VaR model based on a lookback period based on years of crisis will lead to a higher VaR. In the historical VaR model used in this research correlations are based on years 1997-2013. In this time period both years of recession as well as years with low correlations between risk types are taken into account.

5.3 Comparison Historical parametric 97.5% VaR with other models

With the historical parametric 97.5% VaR the standard deviations of positions from a historical look-back period are multiplied by 1.96 to get the amount related to the 97.5% VaR. This method is comparable with the DNB method in which shocks of risk factors are also based on historical standard deviations. One would expect that the calculated parametric VaR based on years 1997-2013 is similar to the DNB model that will be used in 2015, because the values for the parameters in the DNB model in 2015 are also based on recent information.

Comparing VEV all models

Table 5.19 and figure 5.15 show the outcomes of total VEV and VEV per risk type for the average pension fund in the Netherlands for all models. For equity risk the outcomes of the parametric VaR and the DNB model in 2015 are comparable, for interest rate risk, credit risk and active investment risk the outcomes are different.

In the parametric VaR method credit risk is based on the volatility of individual risk curves related to positions. In the DNB model in 2015 the amount of credit risk is determined by predetermined absolute shocks of credit spreads, this is another method of calculation which explains the difference between the values of credit risk of both models.

The value for interest rate risk of the parametric VaR model is significantly higher than the value for interest risk in the DNB model in 2015. This means that the interest rate factors in the DNB model in 2015 are based on different volatilities than the volatilities of the 97.5% parametric VaR. This can be explained by the fact that the volatility of the euro swap curve, which is used in the parametric VaR model, is higher because it is partly based on years of crisis(years 1997-2013).

The parametric VaR for interest rate risk is significantly smaller than that of the VaR model based on historical simulation, which indicates that the real returns of the euro swap curve are not following a normal distribution, which is the assumption with the parametric VaR model. In years of crisis the tails of the distribution of returns are thicker and the 97.5% VaR level is therefore higher, that is why the historical simulation method, which follows the actual returns, gives a higher value for interest rate risk. In paragraph 6.1 the normality of the distribution of historical returns of the euro swap rates is tested.

	Parametric 97.5%VaR	Hist 97.5% VaR	DNB	DNB 2015
Total	211.7	260.8	141.2	181.4
Interest rate risk	134.2	211.3	55.3	56.3
Total equity	123.8	100.9	104.3	126.2
Equity mature	83.5	67	70.4	84.4
Equity emerging	23.6	20.8	19.6	22.4
Private equity	18.7	15.5	20.1	26.8
Direct real estate	1.7	1.7	2.2	2.2
Currency risk	7.2	6.1	12.4	9.3
Commodity risk	0.3	0.3	0.4	0.5
Credit risk	13.2	15.2	9	37.9
Active investment risk	0	0	0	11.8
Diversification effect	-67.0	-73	-40.2	-60.6

Table 5.19: Comparison VEV (bln) average pension fund per risk factor for all models

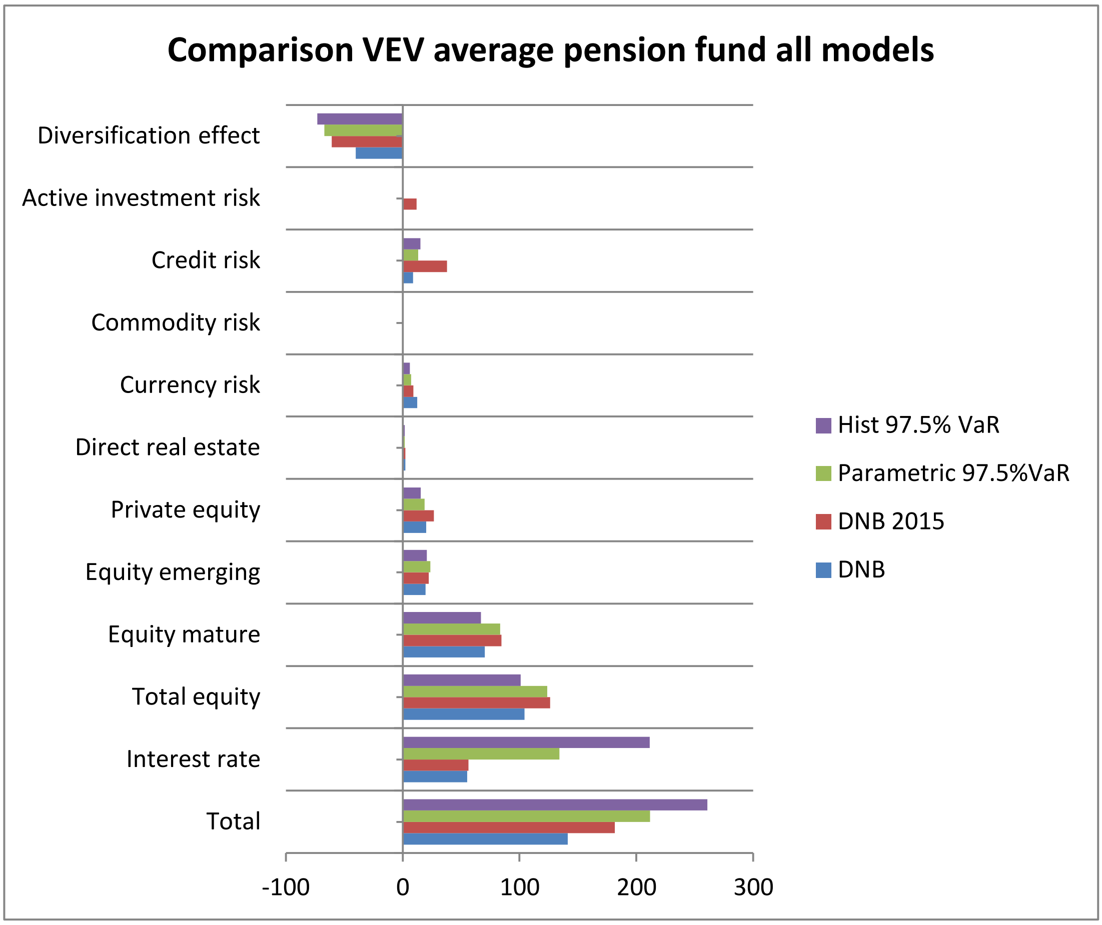


Figure 5.15: Comparison VEV average pension fund per risk factor for all models

Chapter 6: Back-testing individual risk factors on historical benchmarks

In this chapter the outcomes of paragraph 5.2 are back-tested against historical data. In paragraph 6.1 the movements of the euro swap rates are used to back-test the interest rate factors used in the DNB model. Besides that the returns of the euro swap rates are tested on normality to see if the assumption of normality of interest rate returns in the DNB model is correct. In paragraph 6.2 the shocks of the DNB model for all equity types are back-tested against their benchmarks and the historical correlations between equity types are compared with correlations of the DNB model. In paragraph 6.3 the currency buffers are tested against movements of exchange rates. In paragraph 6.4 the commodity buffers are tested against the ACWI commodity producers' index. The shocks related to credit risk are back-tested against the returns of option adjusted credit spreads of different credit ratings in paragraph 6.5. Finally in paragraph 6.6 the 97.5% VaR model is compared with historical benchmarks to see if the VaR model is a good representation of risk related to different historical benchmarks in the same look-back period.

Options chosen for calculation back-tests

Per risk factor a conditional coverage test[51] is done to see if models represent the risk related to a historical time period. Monthly returns of benchmarks related to the risk factors are gathered. The benchmark used per risk type is shown in Table 6.1. For example to test the shock of mature market equity the monthly returns of the MSCI world index are taken as benchmark. In these tests historical monthly returns that fall out of the boundaries relating to the models are counted as exceptions. Monthly boundaries of the DNB models are determined by taking the yearly values for VEV and dividing them by the square root of 12[52]. Monthly returns are chosen in the back-tests to keep the estimation error of turning yearly VEV levels into monthly VEV levels small. If the back-tests were based on 10-day returns, which relate to the 97.5% VaR model, the yearly values of VEV in the DNB models would be divided by the square root of 26 which would lead to a higher estimation error of the 10-day shocks of the DNB models. This is why monthly returns are chosen in the back-tests and not 10-day returns. The back-tests are performed on the same look-back period as the 97.5% historical VaR method, unless the benchmark does not have returns from this period. For most back-tests 191 historical months of data between 1997 and 2013 are taken and the related expected number of exceptions is (1-0.975)*191=5. The corresponding confidence interval of the Kupiec test related to 5 exceptions is (1<x<10). If the number of exceptions falls out of the confidence interval of the expected number of exceptions related to a 97.5% confidence level the VEV model is rejected; so when the number of exceptions x is zero or larger than ten the model is rejected using 191 months of data.

[51] Test with 2 degrees of freedom combining the Christofferson's independence statistic with Kupiec's test to obtain a joint test that has conditional coverage

[52] Square root rule: A 1-year VaR can be turned into a N-year VaR by multiplying the 1-year VaR with $\sqrt{N}$(Hull, p.230)

Risk types	Paragraph	Historical benchmark	Data benchmark
Interest rate risk factors	6.1	Euro swap rates	Monthly returns 1997-2013
Equity mature market	6.2	MSCI world index	Monthly returns 1997-2013
Equity emerging market	6.2	MSCI emerging market index	Monthly returns 1997-2013
Indirect real estate	6.2	EPRA real estate index	Monthly returns 2002-2013
Alternative investments	6.2	Societé generale PRIVEX	Monthly returns 2004-2013
Currency risk	6.3	Exchange rates per currency	Monthly returns 1997-2013
Commodity risk	6.4	ACWI Commodity producers index	Monthly returns 1999-2013
Credit risk	6.5	Barclays Euro-aggregate credit ratings	Monthly credit spreads per credit rating 2003-2013

Table 6.1: Overview of historical benchmarks used for all back-tests performed in chapter 6

6.1 Historical movements of the Euro swap curve in relation to the interest rate risk buffers (S1)

In chapter 5 it was shown that the amount of interest rate risk based on the DNB models was significantly smaller than the amount as outcome of the 97.5% historical VaR model. The interest rate multiplication factors of the DNB model are used to determine the amount of interest risk. In paragraph 2.3 it was explained that the current interest factors are based on Euribor rates between 1997-2005 and German interest rates between 1973-2003. In the calculation of these factors it is assumed that the returns of the interest rates are normally distributed. Looking at the VEV levels for interest risk in chapter 5 one would expect that the current factors of the DNB model underestimate risk related to movements of the euro swap curve. These movements influence the future values of assets related to interest rate risk. To determine this risk these factors should be back-tested.

Transforming interest rate factors into monthly returns
Historical monthly returns of the Euro swap rates on the curve between 1997 and 2013 are gathered to measure the monthly exceptions for the back-test. An exception occurs when a historical monthly interest rate change is larger than the change related to a DNB factor[53]. Table 6.2 shows the factors of the DNB model and the related expected monthly change of the euro swap rate.

[53]Example calculation of exception: The monthly change of the 12-month downward factor in 2015 is: (1-(12month factor))/sqrt(12)=(1-0.49)/sqrt(12)=-14.7%; when the monthly return of the 12-month euro swap rate is lower than -14.7% this return is count as an exception

	Current DNB model				DNB model 2015			
	Factor down	Monthly return down (%)	Factor up	Monthly return up (%)	Factor down	Monthly return down (%)	Factor up	Monthly return up (%)
12-month	0.63	-10.68	1.6	17.32	0.49	-14.72	2.05	30.31
18-month	0.65	-10.25	1.56	16.02	0.52	-13.86	1.9	25.98
24-month	0.66	-9.81	1.51	14.72	0.56	-12.70	1.79	22.81
30-month	0.675	-9.38	1.48	13.86	0.58	-12.12	1.71	20.50
36-month	0.69	-8.95	1.45	12.99	0.61	-11.26	1.65	18.76
48-month	0.71	-8.37	1.41	11.84	0.64	-10.39	1.55	15.88
60-month	0.73	-7.79	1.37	10.68	0.67	-9.53	1.49	14.15
72-month	0.74	-7.51	1.35	10.10	0.7	-8.66	1.44	12.70
84-month	0.75	-7.22	1.34	9.81	0.71	-8.37	1.4	11.55
96-month	0.75	-7.22	1.33	9.53	0.73	-7.79	1.37	10.68
108-month	0.75	-7.22	1.33	9.53	0.74	-7.51	1.34	9.81
120-month	0.76	-6.93	1.32	9.24	0.75	-7.22	1.33	9.53
144-month	0.77	-6.64	1.31	8.95	0.75	-7.22	1.33	9.53
180-month	0.77	-6.64	1.29	8.37	0.75	-7.22	1.33	9.53
240-month	0.78	-6.35	1.28	8.08	0.76	-6.93	1.32	9.24
300-month	0.79	-6.06	1.27	7.79	0.76	-6.93	1.32	9.24
360-month	0.79	-6.06	1.27	7.79	0.76	-6.93	1.32	9.24
480-month	0.79	-6.06	1.27	7.79	0.76	-6.93	1.32	9.24
600-month	0.79	-6.06	1.27	7.79	0.76	-6.93	1.32	9.24

Table 6.2: DNB multiplication factors and related monthly returns interest rate

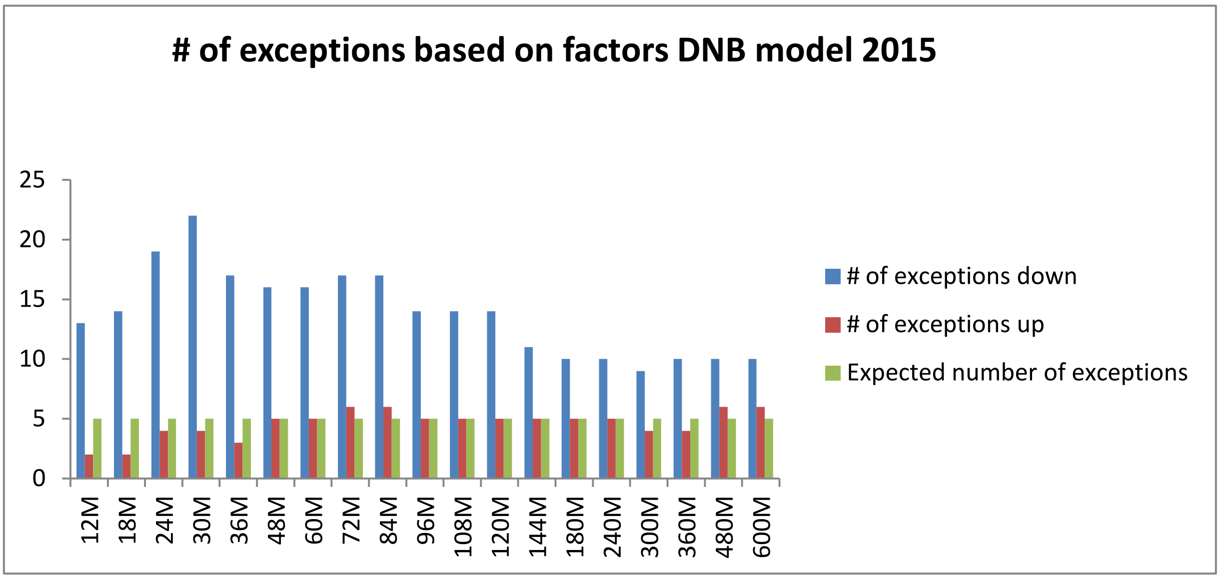


Figure 6.1: The number of exceptions based on movements euro swap curve for both upward as well as downward multiplication factors

Number of exceptions DNB model 2015

Figure 6.1 shows the number of exceptions corresponding to the DNB factors in 2015 and the expected number of exceptions when using 191 months of data. The maximum number of exceptions that is accepted with the conditional coverage test is 10. As can be seen the number of exceptions for 12-month till 120-month interest rates exceed this maximum. The number of exceptions of the 144-month till 600-month interest rates is accepted by the conditional coverage test, but as can be seen in figure 6.1 the number is still high compared with the expected number of exceptions of 5.

	Kupiec's test (N=191;T=5.024[54])				Christoffersen's test (N=191;T=5.024)				Conditional coverage test (N=191 T=7.38[55])			
Points on euro swap curve (in months)	Test value DNB model		Test value DNB model 2015		Test value DNB model		Test value DNB model 2015		Test value DNB model		Test value DNB model 2015	
Factor Down/up	↓	↑	↓	↑	↓	↑	↓	↑	↓	↑	↓	↑
12-month	34.4	0.1	10.0	2.1	7.7	0	7.7	0	42.1	0.1	17.6	2.1
18-month	48.2	0.3	12.1	2.1	6.2	0	6.5	0	54.4	0.3	18.6	2.1
24-month	41.1	0.3	25.1	0.1	5.5	0	4.8	0	46.7	0.3	29.9	0.1
30-month	55.6	1.9	34.4	0.1	9.4	0	11.1	0	65.1	1.9	45.5	0.1
36-month	55.6	1.9	19.5	0.8	2.5	0	6.8	0	58.1	1.9	26.3	0.8
48-month	51.9	0.9	16.9	0.0	1.5	0	7.9	0	53.4	0.9	24.9	0.0
60-month	51.9	1.9	16.9	0.0	3.1	0	7.9	0	55.0	1.9	24.9	0.0
72-month	37.7	3.1	19.5	0.3	6.5	0	6.8	0	44.3	3.1	26.3	0.3
84-month	28.1	0.3	19.5	0.3	3.9	0	3.7	0	32.1	0.3	23.2	0.3
96-month	16.9	0.3	12.1	0.0	0.3	0	0.9	0	17.3	0.3	13.0	0.0
108-month	14.5	0.9	12.1	0.0	0.6	0	0.9	0	15.0	0.9	13.0	0.0
120-month	14.5	0.0	12.1	0.0	0.6	0	0.9	0	15.0	0.0	13.0	0.0
144-month	10.0	0.0	6.1	0.0	1.3	0	0.2	0	11.2	0.0	6.3	0.0
180-month	6.1	0.0	4.5	0.0	2.3	0	0.4	0	8.4	0.0	4.9	0.0
240-month	6.1	0.3	4.5	0.0	2.3	2.3	2.9	0	8.4	2.6	7.4	0.0
300-month	4.5	0.9	3.1	0.1	0.0	1.7	0.0	0	4.5	2.6	3.1	0.1
360-month	6.1	0.3	4.5	0.1	5.8	0	0.4	0	11.9	0.3	4.9	0.1
480-month	8.0	0.9	4.5	0.3	4.8	0	0.4	0	12.7	0.9	4.9	0.3
600-month	10.0	1.9	4.5	0.3	0.0	0	0.0	0	10.0	1.9	4.5	0.3

Table 6.3: The test values of Kupiec's, Christoffersen's and the conditional coverage test

Testing interest risk factors

In Table 6.3 the results of all the tests are shown. The most important test result is the conditional coverage test, which is a joint test based on both Kupiec's test as well as Christoffersen's test. If the test values of the conditional coverage test are higher than the 7.38 critical value of the test, the factor of the DNB model is rejected, which is indicated by the colour red. When the DNB factor passed the test this is indicated by the colour green. As can be seen in Table 6.3 test results of the factors used for upward movements of the interest rate curve are all in the green zone of the conditional coverage test. However the downward factors for the current DNB model are all rejected accept for the 300-month interest rate. Only the long-term (144-months and longer) downward factors that are going to be used in 2015 are not rejected by the conditional coverage test.

Historical monthly returns 240-month euro swap rate

Figure 6.2 shows the returns of the 240-month euro swap rate in the years 1997-2013. As can be seen the volatility of the returns is high from years 2008 till 2013. The number of exceptions that occurs in this time period is high, which can be seen by the movements through the levels related to the DNB models. These levels are the returns related to the DNB factors retrieved from Table 6.2.

[54] T=Critical value based on Chi-square distribution with 1 degree of freedom and P-value of 0.025

[55] T=Critical value based on Chi-square distribution with 2 degrees of freedom and P-value of 0.025

The changes of other euro swap rates show the same trend as the returns related to the 240-month euro swap rate. These figures explain why the value for interest rate risk is very high in the VaR model. This research also shows that the values of VEV for interest rate risk in the DNB models underestimate interest rate risk in times of crisis.

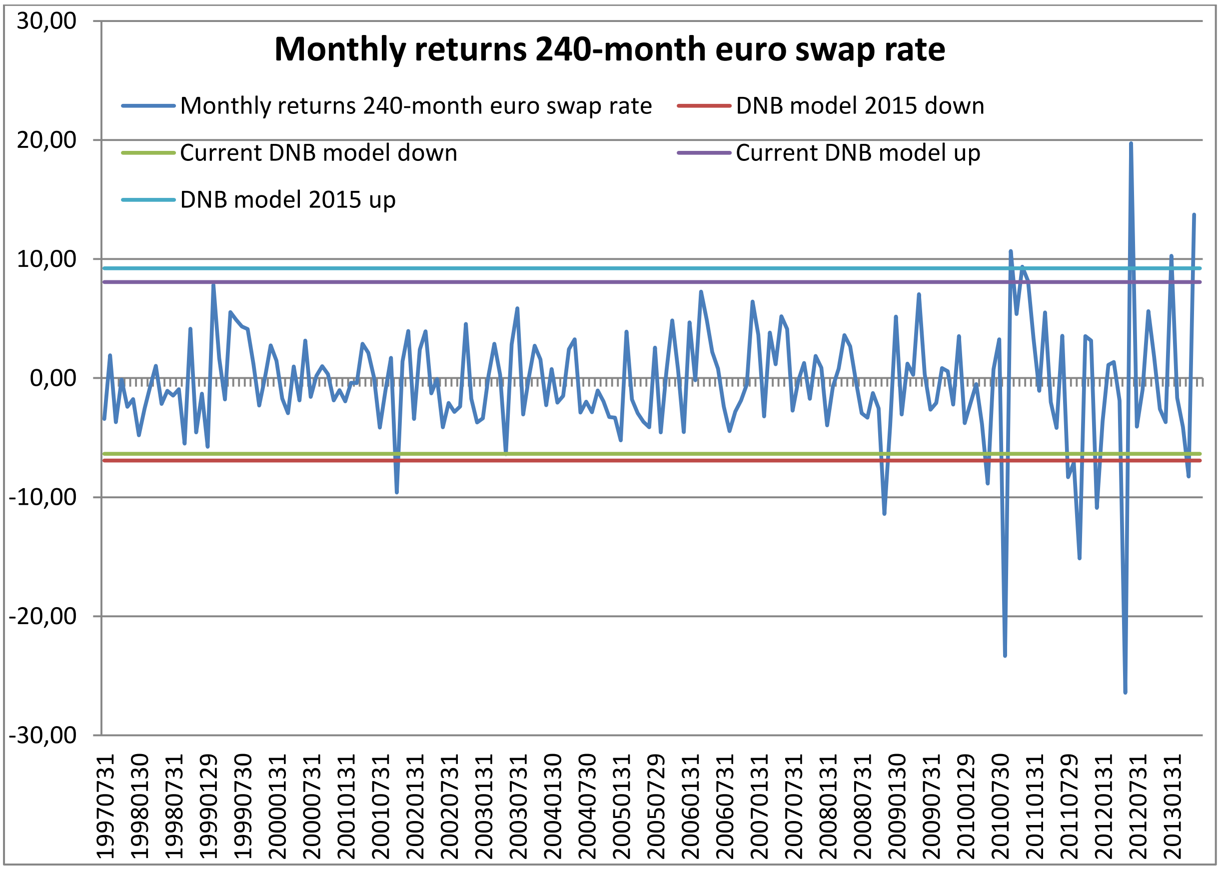


Figure 6.2: Monthly returns 240-month euro swap rate years 1997-2013

Testing normality of monthly returns euro swap rates

The DNB factors are based on the assumption that the relative returns of the euro swap rates are normally distributed. If returns are not normally distributed, but for example have a negative skew, this has a large impact on the VaR, because the number of returns in the left tail is higher, which leads to a higher VaR. Based on this the returns should be tested on normality. This is done by calculating the skewness, kurtosis and the Jarque-Bera test for normality. Skewness is a measure that shows if a distribution of returns is symmetric around the mean. For a normal distribution the skewness is 0. A distribution skewed to the right has positive skewness and a distribution skewed to the left has negative skewness. If a distribution has a negative skewness, this is relevant for the VaR in the model. If the VaR is calculated based on a normal distribution, while the distribution has a negative skewness the VaR model underestimates the risk related to the distribution of returns. The kurtosis is a measure for the thickness of tails of a distribution. The normal distribution has a Kurtosis of three. A higher value than three for the kurtosis means that the distribution has thicker tails than the normal distribution. Thicker tails lead to higher VaR values. The Jarques-Bera test combines the values for skewness and kurtosis in a formula. The Jarques-Bera test statistic can be compared with a chi-square distribution with two degrees of freedom. The critical value for a 97.5% confidence level is 7.378.

$$S = \frac{\hat{\mu}_3}{\hat{\sigma}^3} = \frac{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^3}{\left(\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2\right)^{3/2}}$$

$$K = \frac{\hat{\mu}_4}{\hat{\sigma}^4} = \frac{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^4}{\left(\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2\right)^{2}}, \qquad JB = \frac{n}{6}\left(S^2 + \frac{1}{4}(K-3)^2\right)$$

Formulas for skewness, kurtosis and Jarque-Bera test; where n=number of returns, $x_i$is the i-th return, $\overline{x}$=sample average return

Figure 6.3 shows the frequency of the actual monthly returns of a number of short term, medium term and long term euro swap rates in 1997-2013 versus the frequency of returns that is expected following a normal distribution. It can be seen that for both short term and long term swap rates the distribution has a higher peak and thicker tails then the normal distribution. This means that for these rates it seems that the assumption of normality is not true. The test results in Table 6.4 show if the swap rates follow the normal distribution or not. As can be seen only the 108-month and 120-month swap rate pass the Jarque-Bera test for normality. The mid-term 84-month till 180 month-swap rates have the most similarity with the normal distribution. The short term swap rates show the lowest resemblance with the normal distribution, with high test-values for the Jarques-Bera test and high values for kurtosis.

The high positive values of the skewness and kurtosis of the short term rates are a result of one very high positive return, leaving this return out of the sample; the skewness and kurtosis of these rates are comparable with the skewness and kurtosis of the long term interest rates, which means that the distribution has a small negative skew and a kurtosis that is between 4 and 7. The interest factors of these swap rates should be recalculated based on a model that does not assume a normal distribution of returns. The results of the change of short term factors are examined in chapter 7.

	Skewness (0 for normal distribution)	Kurtosis (3 for normal distribution)	Jarque-Bera test-value(T=7.378)
12-month	3.71	39.38	10,970.08
18-month	4.43	46.24	15,501.44
24-month	4.61	47.30	16,294.80
30-month	4.39	43.78	13,850.81
36-month	2.84	24.46	3,923.80
48-month	2.24	17.50	1,832.49
60-month	1.67	11.93	724.20
72-month	1.17	7.45	201.09
84-month	0.80	5.26	61.20
96-month	0.50	4.04	16.59
108-month	0.29	3.75	7.13
120-month	0.10	3.65	3.65
144-month	-0.18	4.12	11.00
180-month	-0.51	5.52	59.11
240-month	-0.85	6.99	149.42
300-month	-0.82	7.00	148.45
360-month	-0.69	7.18	154.37
480-month	-0.56	6.93	133.10
600-month	-0.47	7.06	138.28

Table 6.4: Tests for normality euro swap rates

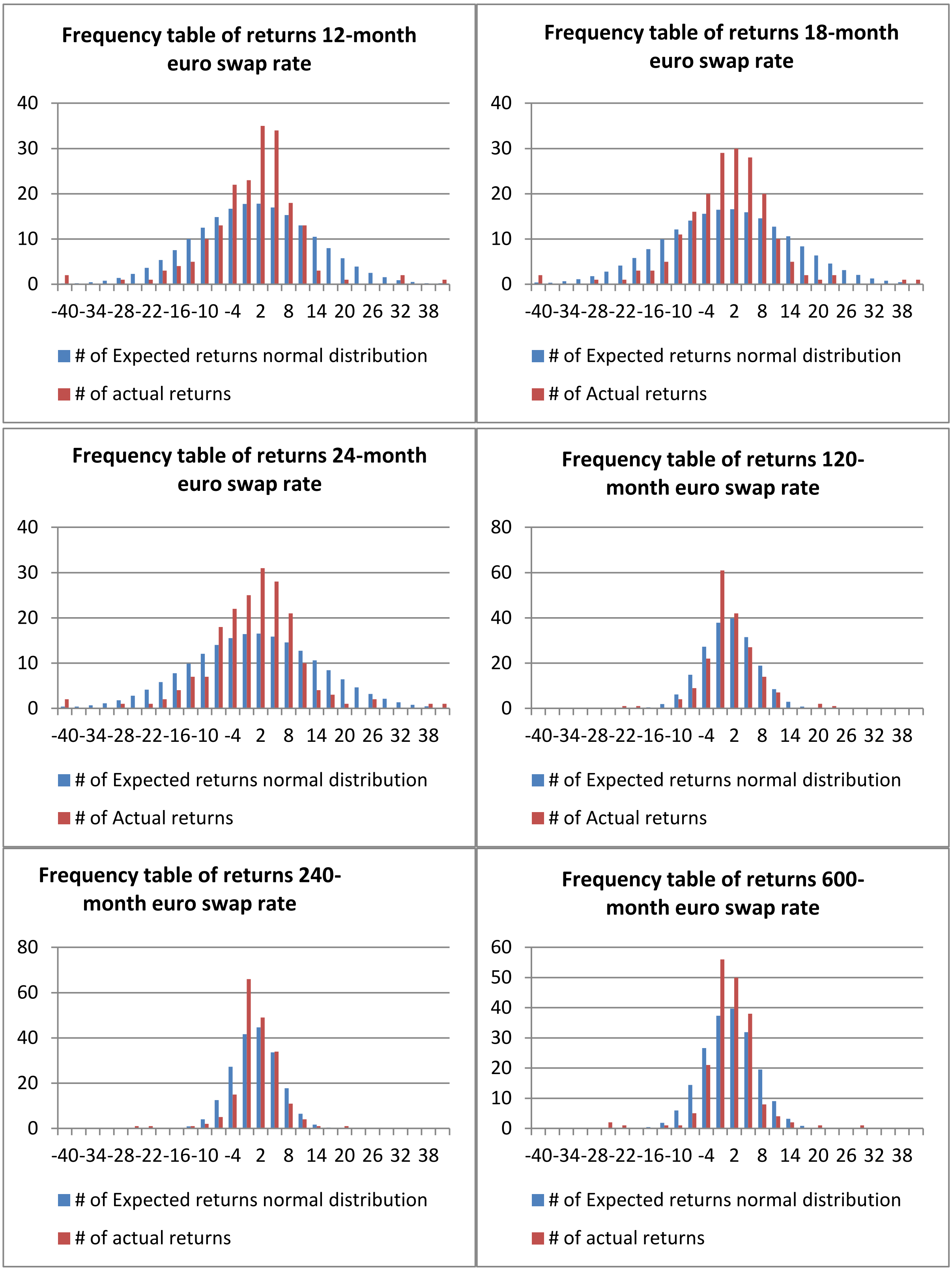


Figure 6.3: Frequency diagrams of actual monthly returns of euro swap rates compared with normal distribution

6.2 Back-testing equity risk buffers per asset category (S2)

The amount of equity risk is the result of the aggregation of equity mature markets, equity emerging markets, alternative investments and real estate. In this paragraph the asset categories are back-tested separately against their related benchmarks.

Mature market equity

The shock for mature market equity is compared with the monthly movements of the MSCI world index in the years 1997-2013.The current yearly shock is -25% and the corresponding monthly shock is-7.22%, which is the yearly shock divided by the square root of twelve. If a monthly return of the MSCI world index is smaller than this value it counts as an exception. As can be seen in Table 6.5 the number of exceptions related to the current shock is 15. The number of expected exceptions based on a 97.5% confidence level is 5 based on a total number of monthly returns of 191. The high number of exceptions results in a rejection in the conditional coverage test, which means that the model underestimates the risk related to mature market equity. For a shock of -30% the model is not rejected, but still has a high test value and for a shock of -35% the number of exceptions is 5, which is the expected number of exceptions. Figure 6.4 shows when the monthly returns of the MSCI world index went through the boundaries related to different shocks.

Equity mature against MSCI world index						
		Kupiec's test (N=191; T=5.024)		Christoffersen's test (T=5.024)	Conditional coverage-test (T=7.38)	Basel traffic light approach
Model	Monthly return	# of exceptions	Test value	Test value	Test value	# of exceptions
-25(DNB current)	-7.22	15	19.5	1.4	21.0	17
-30(DNB 2015)	-8.66	10	4.5	0	4.5	10
-35	-10.10	5	0	2.7	2.7	5
-40	-11.55	3	0.8	0	0.8	2

Table 6.5: Test values equity mature markets DNB models

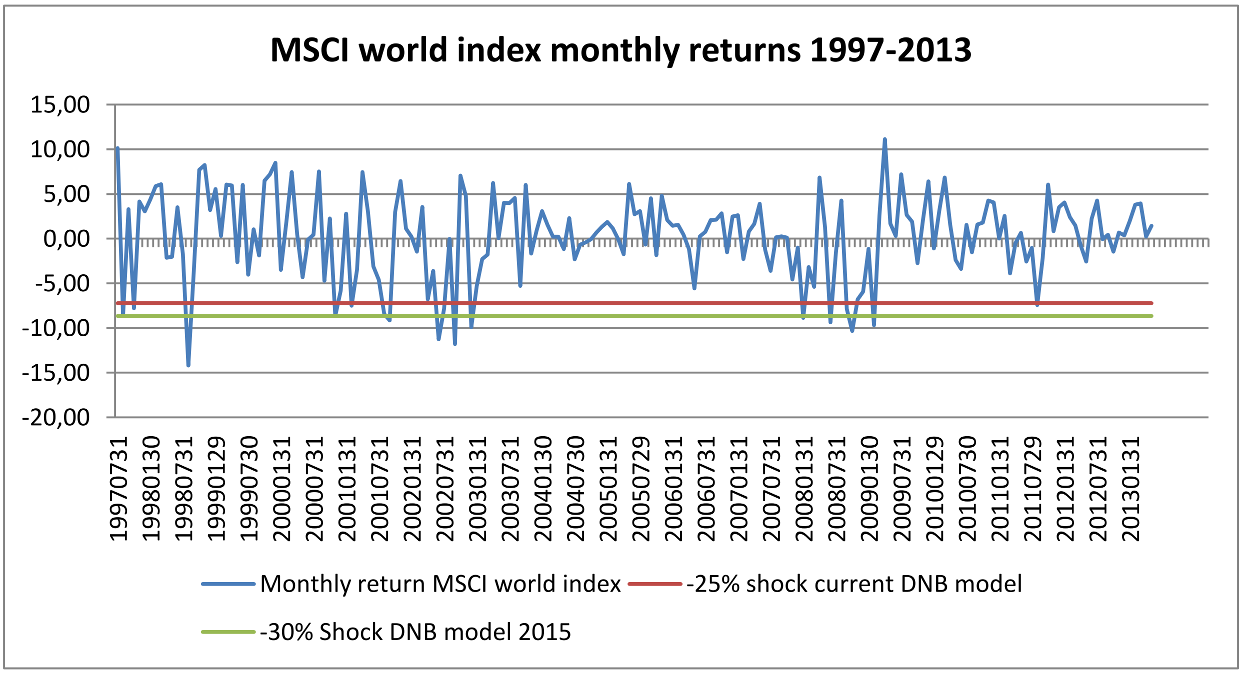


Figure 6.4: Monthly returns MSCI world index years 1997-2013

Comparing historical monthly returns MSCI with positions in 97.5% VaR model

Comparing the results of the back-tests based on the MSCI world index in chapter 6 and the results of the VaR model in chapter 5 there is a contradiction. The VaR model has a lower value of VEV than the DNB model in 2015, while the back-tests indicate that the DNB shock should be adjusted to the -30% shock in 2015. The relatively low value of the VaR model can be caused because a high decrease in value of one position can be compensated by a low decrease in value for another position. The VaR level in the historical simulation model is a result of aggregation of simulated results of all positions and their correlations. In a well-diversified portfolio, this can result in a diversification advantage. However the movements of the MSCI world index are also an average of the world market movements and therefore a diversification advantage is also occurs in this index. Another reason for the low values in the VaR model is that the positions of the average pension fund have relatively low volatility compared to the MSCI world index. The returns of the MSCI world index have a yearly standard deviation of 15.87%, while the standard deviation of mature market equity for the average pension fund in the historical VaR model is 12.50%. This explains the relatively low values in the VaR model.

Emerging market equity

Shocks for emerging market equity of both DNB models are compared with the MSCI emerging market index. Looking at the test values of the conditional coverage test in Table 6.6 the current shock of -35% used in the DNB model leads to a test value of 15, which leads to a rejection of the model. The number of exceptions is high, which means that the current model underestimates risk of equity emerging markets. However the shock of -40% which will be used in 2015 leads to less exceptions and is therefore not rejected by the conditional coverage test.

Equity emerging markets against MSCI emerging markets index						
		Kupiec's test (N=191; T=5.024)		Christoffersen's test (T=5.024)	Conditional coverage-test (T=7.38)	Basel traffic light approach
Model	Monthly return	# of exceptions	Test value	Test value	Test value	# of exceptions
-35(DNB current)	-10.10	15	14.5	0.6	15.0	15
-40(DNB 2015)	-11.55	10	4.5	0.4	4.9	10

Table 6.6: Test values equity emerging markets DNB models

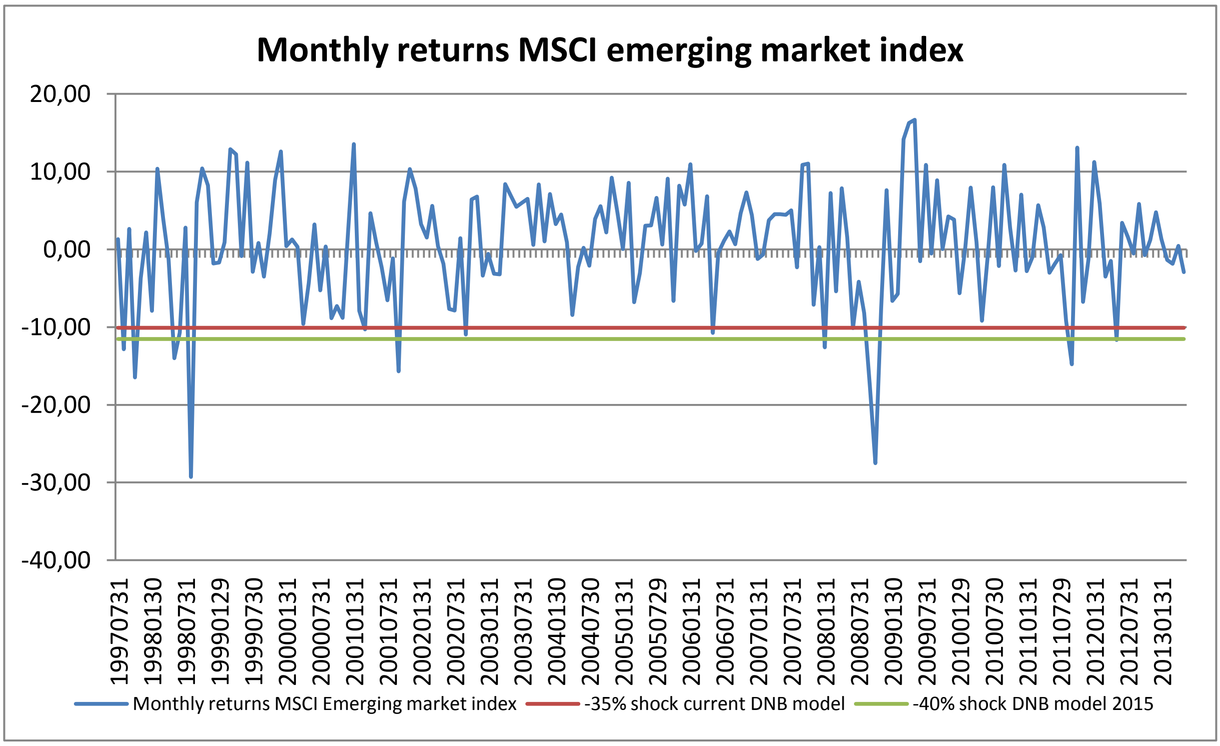


Figure 6.5: Monthly returns MSCI emerging market index years 1997-2013

Comparing monthly returns MSCI emerging market index with positions historical VaR model
As can be seen in figure 6.5 the volatility of the monthly returns of the emerging market index is high, the yearly standard deviation is 25.46% in the years 1997-2013. The high volatility leads to the rejection of the current DNB model, because the number of times the returns went through the line representing the -35% shock is 15, which is too much according to the conditional coverage test. The standard deviation of the emerging market assets in the average pension fund in the Netherlands used in the VaR model is 17.30%; this explains the relatively low value for equity emerging markets in the model compared to the emerging market index.

Indirect real estate
The benchmark for indirect real estate is the EPRA real estate index. In the DNB model indirect real estate is considered as mature market equity with a shock of -25% in the current model. The test value of the conditional coverage test in Table 6.7 is 13.4, which is higher than the critical value. Based on the high number of exceptions the current model underestimates risk related to indirect real estate and is rejected. The shock of -30% that will be used in 2015 is not rejected by the conditional coverage test.

Indirect real estate against EPRA real estate index						
		Kupiec's test N=129 (T=5.024)		Christoffersen's test (T=5.024)	Conditional coverage-test (T=7.38)	Basel traffic light approach
Model	Monthly return	# of exceptions	Test value	Test value	Test value	# of exceptions
-25 DNB current	-7.22	9	7.2	6.2	13.4	9
-30 DNB 2015	-8.66	5	0.9	2.0	2.8	5
-35	-10.10	3	0.0	4.1	4.2	3

Table 6.7: Test values indirect real estate DNB models

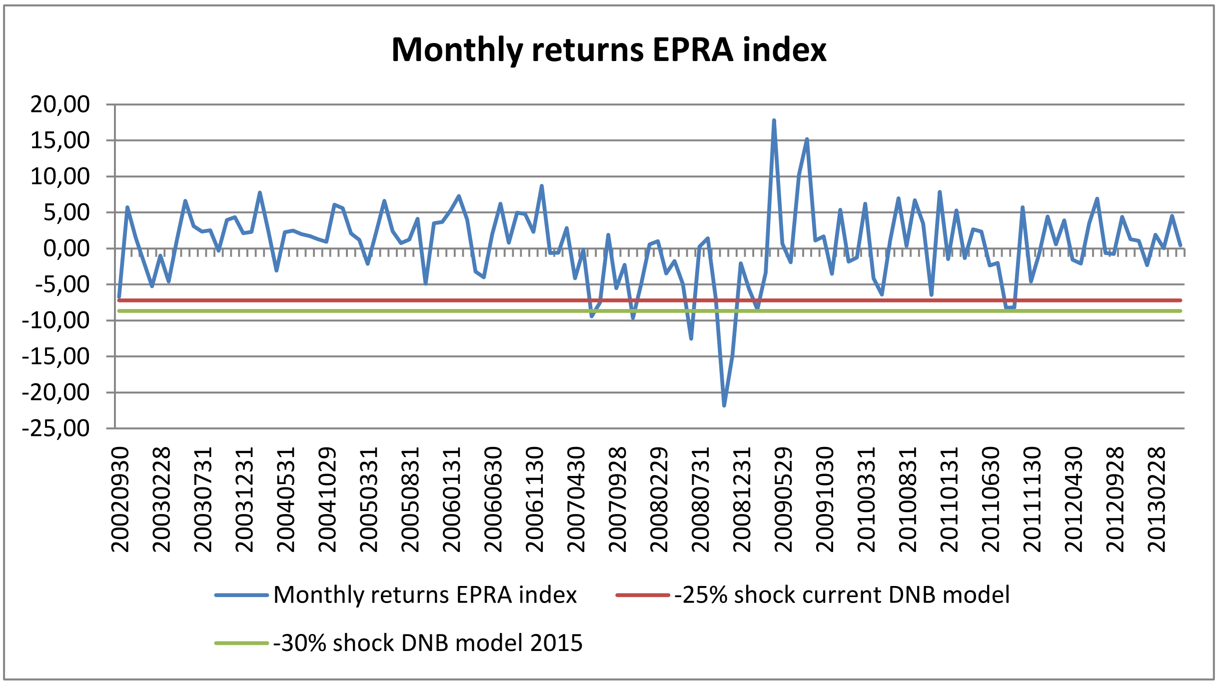


Figure 6.6: Monthly returns years 2002-2013 EPRA index

In figure 6.6 it can be seen that the monthly exceptions for the current DNB model is high, the monthly returns go through the boundary a total of nine times, which is too much for a sample of 129 months.

Private equity and hedge funds

For back-testing the DNB shocks for private equity the monthly returns of the Private equity index (PRIVEX) of Societé Generale are used as benchmark. The PRIVEX index includes the 25 most representative stocks of the private equity companies listed on the world stock exchanges. The index is balanced every quarter. In Table 6.8 both shocks of DNB models are not rejected by Kupiec's test. The number of exceptions is acceptable. However since the exceptions are clustered the test values for Christoffersen's test are high, this is why the models are rejected by the conditional coverage test.

Private equity and hedge funds against PRIVEX (Private Equity Index) Societé Generale						
		Kupiec's test N=124 (T=5.024)		Christoffersen's test (T=5.024)	Conditional coverage-test (T=7.38)	Basel traffic light approach
Model	Monthly return	# of exceptions	Test value	Test value	Test value	# of exceptions
-30 DNB current	-8.66	5	1.0	7.2	8.2	5
-40 DNB 2015	-11.55	3	0.0	12.9	12.9	3

Table 6.8: Test values private equity and hedge funds DNB models

Because of the relatively small sample of data (N=124 months) the results of high test values in Table 6.8 are strongly depending on the period chosen and test values should be treated carefully. These test values are based on a recent period (years 2004-2013), which is a good period to test the DNB model that will be used in 2015.

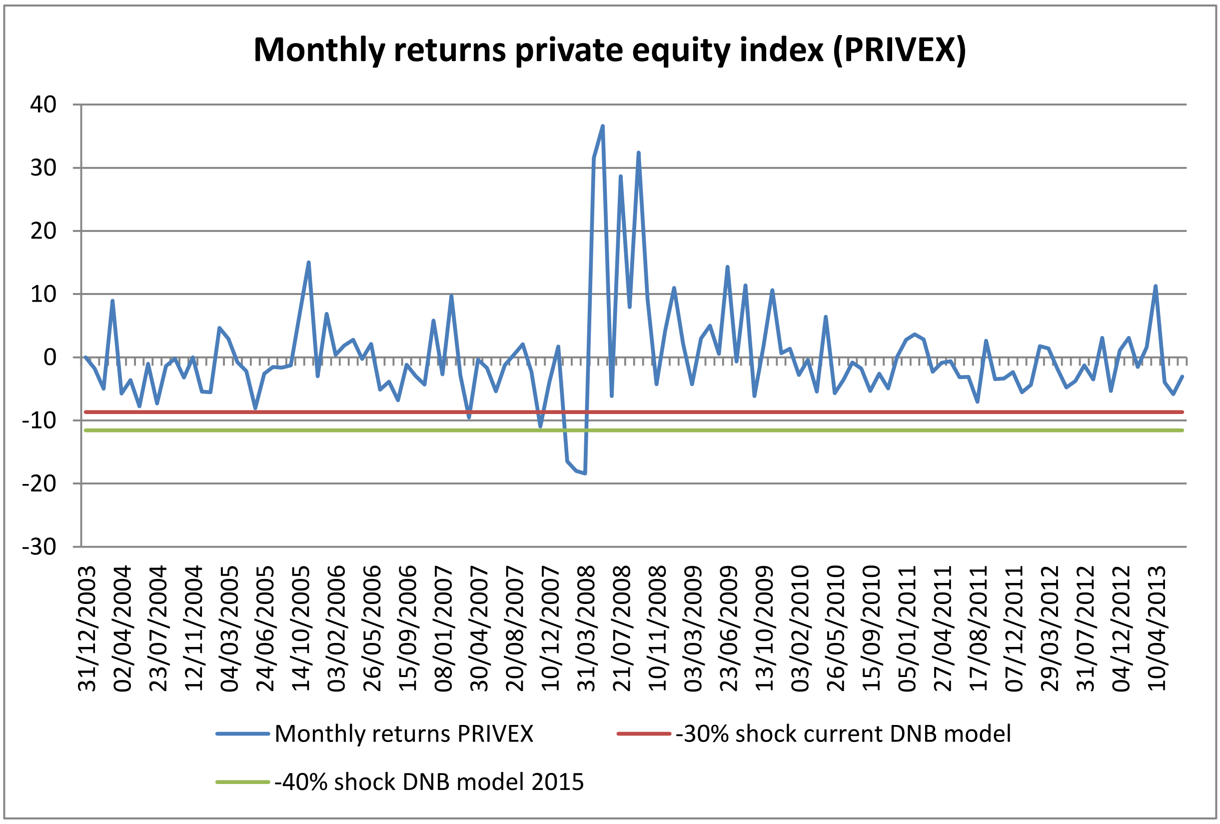


Figure 6.8: Monthly returns years 2004-2013 private equity index

The clustering of exceptions can be seen in figure 6.8, all exceptions related to the DNB model in 2015 occur in 2008. As can be seen in this figure large periods of relatively low volatility are followed by short periods of high volatility. This is a consequence of the fact that the valuation of private equity is based on quarterly figures. Based on the long periods of low volatility and the short periods of high volatility and the clustering of exceptions in the periods with high volatility one would expect that the returns of the Private Equity Index are not normally distributed. Figure 6.7 compares the frequency of returns of the Private Equity Index with the frequency of returns of the normal distribution. The frequency of returns around zero is very high; this is in line with the long periods of low volatility. The tails of the distribution are fat, which means that the number of both very high returns and very low returns is higher than the normal distribution.

Comparing monthly returns private equity index with historical VaR model

The yearly standard deviation of the positions in private equity and hedge funds of the average pension fund in the Netherlands in the VaR model is 14.93%. This is relative low compared to the standard deviation of 28.02% for the private equity index. This extremely high standard deviation is caused by the year 2008, where the volatility was extremely high. Because the standard deviation is computed for the years 2004-2013, instead of a longer time period, the values of 2008 have a high influence on the result. The relatively low volatility in the VaR model leads to a low value of the VaR level; this explains why the value of VEV for alternative investments in the VaR model is significantly lower than the value in the DNB models.

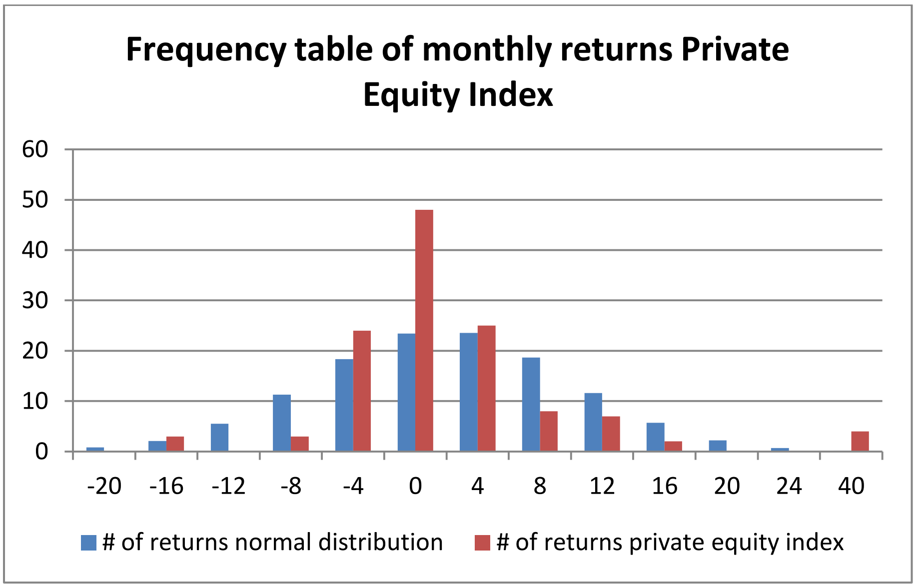


Figure 6.7: Frequency table of returns private equity index

6.3 Back-testing currency risk buffer (S3)

In this paragraph both the baskets of foreign currencies in the DNB model and the VaR model are back-tested using monthly changes in currency exchange rates. The test values of the movements of individual currencies used in the baskets are shown as well, which is interesting for pension funds that have a large exposure to an individual currency. For example a pension fund can have a large amount of unhedged assets in us dollars. In the current DNB model the VEV for currency risk is determined using a shock of -20% for all assets exposed to foreign currencies. The DNB model in 2015 has the following scenarios for different portfolios:

1. Portfolios with a well spread mix of currency exposure with at most 30% currency exposure in emerging markets. A shock of -15% is used for this case.
2. Portfolios were the currency exposure exists of a single mature market. A shock of 20% is used for this case
3. Portfolios were the currency exposure mainly exists of emerging markets. A shock of 30% is used for this case.
4. Portfolios were the currency exposure exists of one emerging market. A shock of 35% is used for this case.

Back-testing currency buffers									
	Kupiec's test (N=191 Critical value=5.024)					Christoffersen's test (T=5.024)		Conditional coverage test (T=7.38)	
	DNB current (-20% shock)		DNB 2015			DNB (-20%)	DNB 2015	DNB (-20%)	DNB 2015
Portfolio currencies	# of except-ions	Test value	shock	# of except-ions	Test value	Test value	Test value	Test value	Test value
1: DNB basket	1	4.5	-15%	4	0.1	-	-	4.5	0.1
1: VaR model basket	1	4.5	-15%	3	0.8	-	-	4.5	0.8
2: Australian dollar	7	0.9	-20%	7	0.9	-	-	0.9	0.9
4: Brazilian Real	19	25.1	-35%	7	0.9	2.0	1.4	27.1	2.3
2: Swiss Franc	0	9.6	-20%	0	9.6	-	-	9.6	9.6
2: British pound	2	2.1	-20%	2	2.1	-	-	2.1	2.1
2: Japanese Yen	7	0.9	-20%	7	0.9	3.0	3.0	4.0	4.0
2: Swedish Krona	2	2.1	-20%	2	2.1	-	-	2.1	2.1
2: US dollar	5	0.0	-20%	5	0.0	-	-	0.0	0.0

Table 6.9: Test values currency shocks DNB models

Comparing test values DNB models
The test values of Kupiec's test of both the current DNB basket as well as the basket in the VaR model are 4.5, which is close to the critical value of 5.024, which means that the models are close to rejection but not rejected. The number of exceptions for both baskets is one, which is very small. In other words the current DNB model overestimates currency risk when currencies are well spread as is the case for the DNB basket and VaR model basket. The test values related to a shock of -15% which will be used in the DNB model in 2015 are close to zero and therefore give a better representation of the currency risk of both baskets of currencies. As can be seen in Table 6.9 the current DNB model does not give a good representation of the risk of currency exposure of currencies of emerging markets. In this test the Brazilian Real went through the -20% boundary 19 times. The means that if pension funds which have a portfolio with a large exposure to a foreign currency of a emerging market, in this case the Brazilian real, the current DNB model underestimates this risk. The shock for exposure to emerging markets of -35%, which will be used in 2015, is not rejected by the conditional coverage test.

6.4 Back-testing commodity risk buffer (S4)

The shocks related to commodities are back-tested using monthly returns of the ACWI commodity producers' index. The current shock for commodity risk in the DNB model is 30%. In Table 6.10 the current shock leads to a number of exceptions of 10 and a test value of 5.5 for Kupiec's test. This leads to a rejection of the current model. However the test value of the conditional coverage test is 5.8, which is lower than the 7.38 critical value and therefore the current model is not rejected by the conditional coverage test. The -35% shock that will be used in the model of 2015 is not rejected by both Kupiec's test as well as the conditional coverage test.

ACWI commodity producers index						
		Kupiec's test N=174 (Critical value=5.024)		Christoffersen's test (T=5.024)	Conditional coverage-test (T=7.38)	Basel traffic light approach
Model	Monthly return	# of exceptions	Test value	Test value	Test value	# of exceptions
-30 DNB current	-8.66	10	5.5	0.3	5.8	10
-35 DNB 2015	-10.10	7	1.4	1.3	2.7	7

Table 6.10: Test values commodities DNB models

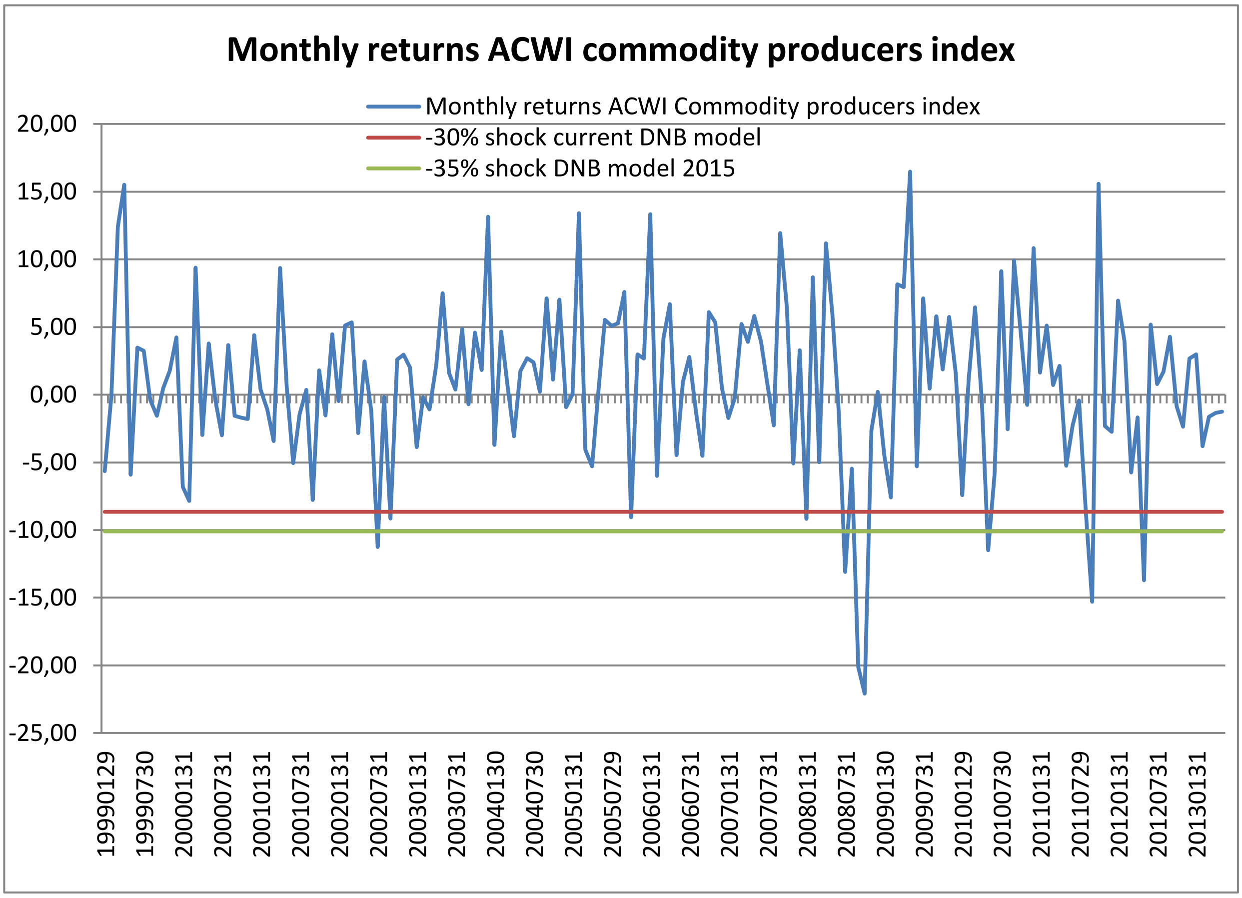


Figure 6.9: Monthly returns ACWI commodity producers' index years 1999-2013

Historical monthly returns ACWI commodity producer's index

The yearly standard deviation of the returns of the ACWI commodity producer's index is 21.34%, while the standard deviation of the average pension fund in the Netherlands is 15.26%. This explains the relatively low value in the VaR model for commodity risk. Figure 6.9 shows the monthly returns of the ACWI commodity producer's index and the exceptions that occur in the years 1999-2013. According to this figure the current DNB model underestimates commodity risk, because exceptions occur during the entire historical period. Therefore the adjustment to a 35% shock in 2015 gives a better representation of the amount of risk for investments in commodities.

6.5 Back-testing credit risk buffer (S5) using historical movements of credit spreads per credit rating category

The values for credit risk in the DNB model are determined by a multiplication of the yearly credit spread with 0.4 in the current model and a shock of an absolute number of basis points per year per credit rating in the DNB model that will be used in 2015. To back-test these shocks yearly changes of credit spreads per credit rating are needed. However because there is only a limited amount of years available as historical data the yearly changes of credit spreads are simulated using monthly changes of option adjusted credit spreads per credit rating between April 2003 and April 2013. A yearly change is simulated using the bootstrap method, which will be explained next.

Bootstrap method[56] to calculate the yearly change of credit spreads

- Step 1: Calculate monthly returns of credit spreads using historical data
- Step2: Randomly select twelve monthly returns from the data in step 1
- Step3: Multiply the current value (t=0) of the credit spread with the selected twelve monthly returns to get a future value of the credit spread for periods t+1, t+2,…t+12 with t as the number of months
- Step4: Calculate the yearly change between credit spread at time t=0 and credit spread at time t=12
- Step5: Repeat step 1-4 n times to get n trials of yearly changes of credit spread

With the bootstrap method the expected yearly change is calculated by multiplying the value of the credit spread of the 31th of December 2012 with the twelve historical monthly returns which were randomly selected to get an expected yearly change based on historical data. This calculation is repeated 200 times to get 200 trials of yearly changes.

Disadvantage of the bootstrap method is that it does not take into account correlation between successive returns, which means that returns are considered to be independent. Therefore the value for Christoffersen’s test is low because of randomly selected returns.

Results test values DNB models

A yearly change larger than the shock in the DNB model is counted an exception for Kupiec’s test. The results of the conditional test are shown in Table 6.11. The test values for the relative shock used in the current DNB model are very high, which means that based on simulated changes of option adjusted credits spreads of the years 2003 till 2013 the current model is rejected, because it is underestimating credit risk. The absolute shocks of credit spreads with ratings A, AA and AAA are all in the green region and therefore not rejected by the conditional coverage test. The returns of credit spreads with BBB ratings lead to a high number of exceptions and a high test value for the conditional coverage test and therefore the shock of 180 basis points for BBB rated assets is rejected. The influence of decreasing and increasing the absolute shocks per credit rating on VEV levels are shown in a sensitivity analyses in chapter 7.

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[56] Bionicturtle.com. (2008, April 10).*Bootstrapping value at risk.* Retrieved from: http://www.youtube.com/watch?v=FFSDsTqopZ0

Backtesting credit risk shocks with simulated yearly credit spreads						
		Kupiec's test (N=200; T=5.024)		Christoffersen's test (T=5.024)	Conditional coverage test (T=7.38)	Basel traffic light approach
Relative shock	Relative shock	# of exceptions	Test value	Test value	Test value	# of exceptions
AAA	0.4	36	85.3	0.1	85.4	36
AA	0.4	41	107.6	0.5	108.1	41
A	0.4	34	76.9	0.0	76.9	34
BBB	0.4	33	72.8	0.1	72.9	33
Absolute shock	Absolute shock	# of exceptions	Test value	Test value	Test value	# of exceptions
AAA	60 bps	2	2.4	0	2.4	2
AA	80 bps	5	0	0	0	5
A	130 bps	10	4.0	0.4	4.4	10
BBB	180 bps	23	35.9	0.1	36.0	23

Table 6.11: Test values credit shocks per credit rating DNB models

Monthly changes credit spreads years 2003-2013

Figure 6.10 shows the monthly absolute changes of credit spreads from credit ratings AAA and AA. As can be seen the changes in the years 2003-2007 are small and with the beginning of the financial crisis in 2008 the volatility of the credit spreads is much higher than in the years before the crisis. The relative factor of the current DNB model is overestimating credit risk in the years before crisis and underestimating risk in the years with high volatility. Based on this information it is hard to predict a yearly change of a credit spread based on a parametric model, because the value of the parameter is fixed and the estimation error is therefore high. The parameters that will be used in 2015 seem accurate to predict current changes of credit risk, but these factors will overestimate credit risk in a future period of low volatility.

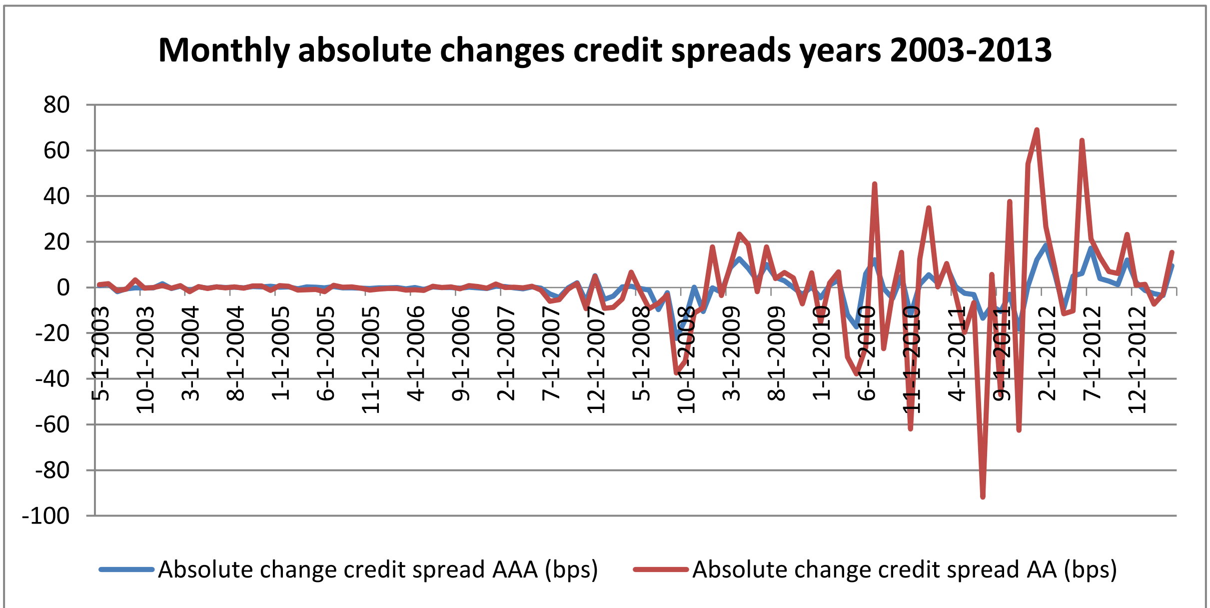

Figure 6.10: Absolute changes in basis points of credits spreads from 30th of April 2003 till 30th of April 2013

6.6 Model Validation: Comparing the 97.5% VaR model with historical benchmarks

VaR levels equity risk, currency risk, commodity risk and credit risk
The VEV levels for equity risk, currency risk, commodity risk and and credit risk of the 97.5% historical VaR model are relatively low compared with the VEV values of the DNB model in 2015. Based on the 97.5% VaR model the adjustments to the DNB model in 2015 are overestimating these risk factors. In this chapter the shocks of the DNB model were back-tested against historical benchmarks. Based on these back-tests the adjustments in the DNB model are necessary. The relatively low values in the 97.5% VaR model can be explained by the following reasons:

- **Equity and commodity risk:** The positions in equity mature markets, emerging markets, private equity and hedge funds and commodities in the 97.5% VaR model all have lower volatilities than their related benchmarks during the look-back period between years 1997-2013
- **Equity risk:** Smaller correlations between direct real estate and other equity types: The correlations between direct real estate and the other equity types in the look-back period are significantly lower than the 0.75 of the standard model, the 97.5% VaR model is based on real correlations between positions, and this explains that the total VaR for equity risk is lower.
- **Currency risk:** Diversification advantage spreaded portfolio of currencies: Exposure to foreign currencies in the VaR model is low because the portfolio is well spread. Movements of one currency are compensated with movements of other currencies in a well-spread portfolio. The positions in US dollars, which is a large percentage in the assets mix, have a negative incremental VaR, which means that there contribution decreases the total VaR for currency risk. In the back-tests with historical currency exchange rates the diversification effect is seen as well.
- **Credit risk:** Changes of credit spreads of AAA and AA rated assets in the 97.5% VaR model are low compared to absolute shocks in DNB model. The credit spreads of zero coupon German and Dutch government curves are even negative for short term maturities, which means that these curves are less risky than the zero coupon euro swap curve, which is considered as the riskless curve. Because the percentages of the credit curves are low for AAA rated assets in the VaR model, the absolute changes of credit spread are low as well. The back-tests of returns of credit spreads per credit rating also show low volatility for AAA rated assets.

High VaR for interest rate risk in historical 97.5% VaR model
The high VaR level for interest rate risk in the historical VaR model is in line with the back-tests of DNB factors against movements of euro swap rates. The high volatility of monthly euro swap rates in the back-tests explains the high value for interest rate risk in the VaR model. The high values in the VaR model can be explained by the fact that 10-day interest rate returns are used to determine a yearly VaR for interest rate risk. These rates show high volatility. Based on this information you can argue that yearly changes of interest rates give a more realistic result of VEV. However it is not possible to use yearly returns for a good estimate of a 97.5% VaR, because the limited amount of historical data available.

Chapter 7: Suggestions for adjustments to the standard DNB model

The standard model of the DNB is compared with the historical VaR model and back-tested against historical data. Based on these comparisons suggestions for adjustments to the standard model are presented in this chapter. In paragraph 7.1 the constraints of changing to an internal model are shown. In 7.2 adjustments to parameters of the DNB model are proposed and in 7.3 suggestions are given to add risk factors to the model.

7.1 Constraints for changing to internal VEV model according to DNB documents

In DNB documents[57] the following constraints are mentioned to justify the use of a (partial) internal model instead of the DNB model:

- The solvability buffer of an internal model is measured based on a confidence level of 97.5% with a horizon of one year
- There should be a verifiable material deviation of the risk profile of a product or product category compared with the assumptions of the standard model
- Partial internal models cannot be used to replace existing scenarios in the standard model by scenarios that are determined internally
- The adding of extra risks should be consistent with other risk scenarios
- The result of VEV of an additional risk factor is added to the outcome of the standard model, with this method pension funds do not have to show full cohesion between factors of the internal model and the risk factors of the standard model
- Acceptation of an internal model is temporary; an internal model should be back-tested periodically, at least one time a year, to see if the use of the internal model is still valid

7.2 Adjustments to the parameters of the standard model

7.2.1 Interest rate risk

The short term (1-10 years) interest risk downward factors do not represent the risk to movements of the euro swap curve. Looking at back-tests with movements of the euro swap curve, the downward factors have led to too many exceptions. This means that the amount of VEV for interest rate risk is too low. This is partly compensated by the high correlation in the DNB model between interest risk and business risk. The current DNB model uses a correlation of 0.65, while in the VaR model the real correlation between these two risk factors is 0.32 based on years 1997-2013. The interest risk factors in the standard DNB model are based on the assumption that the returns follow a normal distribution, while back-testing showed that the distributions of short-term and long-term swap rates have higher peaks and thicker tails than the normal distribution.

Changing downward interest rate factors

In Table 7.1 the change of risk factors of the standard model in 2015 is shown. The adjusted risk factors are barely accepted by the back-tests based on historical euro swap rates, which means that these factors result to a number of exceptions of 10 in the back-tests. The calculation of interest rate risk for the standard VEV model with these new factors results in an insignificant change for VEV for

[57] Herziening berekeningssystemathiek VEV, p.14-15

interest risk. This is because the change of the present value of short term liabilities is compensated by the change of the short term assets, in other words the difference between assets and liabilities does not increase. Based on this research the change of short-term interest rate factors is not the solution to the underestimation of interest rate risk in the standard model.

Swap rate	Risk factor DNB model 2015	Adjusted risk factor
12-month	0.49	0.42
18-month	0.52	0.44
24-month	0.56	0.45
30-month	0.58	0.48
36-month	0.61	0.53
48-month	0.64	0.56
60-month	0.67	0.6
72-month	0.7	0.63
84-month	0.71	0.67
96-month	0.73	0.69
108-month	0.74	0.69
120-month	0.75	0.71
144-month	0.75	0.73
VEV interest rate risk[58]	**55.6**	**55.7**

Table 7.1: The amount of VEV for interest rate risk as a result of changing risk factors DNB model 2015 for the average pension fund in the Netherlands

7.2.2 Correlations real estate risk with other equity types

Looking at correlations between equity types in the VaR model compared to the DNB model, ccorrelations between direct real estate and the other equity types are significantly lower than the 0.75 in the DNB model. These correlations can be replaced by alternative correlations based on the historical look-back period of 16 years from 1997 till 2013, which were shown in Table 5.10. In Table 7.2 the effect of these changes for the total amount of VEV for equity risk per synthetic pension fund can be seen. The change of VEV for equity risk with alternative correlations is very small. This is because the weight of direct real estate in the asset mixes of the pension funds is low; the weight of direct real estate is 1.5% of the total asset mix for average pension fund. For these reasons and for the simplicity of the DNB model the correlations between equity types should remain the same. However when a pension fund has a high weight of investments in direct real estate in its portfolio, it should consider the fact, that the DNB model overestimates the risk to correlations between real estate and other equity types.

	VEV Average pension fund NL		VEV high risk		VEV moderate risk		VEV low risk	
	Current model	Model 2015	Current model	Model 2015	Current model	Model 2015	Current model	Model 2015
Correlations of 0.75	104.3	126.2	120.2	145.5	93.2	113	67.9	80.8
Alternative correlations Direct Real estate	103.7	125.6	119.6	144.8	92.6	112.4	67.6	80.5
Change VEV equity risk	-0.58%	-0.48%	-0.50%	-0.48%	-0.65%	-0.53%	-0.44%	-0.37%

Table 7.2: Effect on VEV equity risk of the change of correlations direct real estate with other equity types

[58] VEV is calculated based on actual cash flows of assets and liabilities; therefore there is a small difference between this result and the result for the DNB model in 2015 shown in chapter 5, which is based on an average duration of assets and liabilities.

7.2.3 Credit risk

The relative shocks for credit risk that are used in the current DNB model are not accepted by the back-tests in chapter 6. This means that these shocks do not give a good representation of credit risk and the calculation for the credit risk buffer should be changed.

The amount for credit risk in the DNB model in 2015, that will be calculated based on absolute shocks of credit spreads, overestimates credit risk compared with the historical VaR method. However based on historical back-tests using monthly credit spreads per credit rating between 2003 and 2013 the absolute shock for assets with credit rating BBB underestimates credit risk and other shocks are accepted. The absolute shock for AAA rated assets of 60bps seems high and has a large influence on the amount of VEV.

Changing absolute shocks in credit spreads

In Table 7.3 a sensitivity analyses is performed for different absolute shocks per credit rating. The number of exceptions of simulated yearly changes of credit spreads between 2003 and 2013 is determined for different shocks. Besides that the total amount of VEV for credit risk for the average pension fund in the Netherlands is shown, this is calculated by adjusting the shock for one credit rating and leaving the other credit spread changes the same as the values in the standard model in 2015.

As can be seen changing the shock for AAA rated assets has the largest influence on the amount of VEV, this is because this group has the highest weight in the portfolio. Based on the back-tests the shock of 60bps can be adjusted to a shock of 25 bps and the model will still be accepted. This change has a huge impact on the amount of VEV, which decrease from 37.9 to 27.8, which is a decrease of more than 10 billion. Assets with credit ratings AAA are mostly bonds from low risk governments like Germany and the Netherlands, these assets have very low credit spreads and the amount of risk based on an absolute change of credit spread of 60bps for these assets is not realistic.

The shock of 180bps for assets with BBB rating is not accepted by the conditional coverage test as described earlier in chapter 6. Based on the sensitivity analyses it should be adjusted to at least 250bps. This leads to an increase of VEV of 3.2 billion for the average pension fund in the Netherlands

Changes of credit spreads of assets that have a rating smaller than BBB cannot be back-tested because there are different assets with different credit ratings within the group. However this group has a small influence on the amount of VEV as can be seen in Table 7.1. Therefore the absolute change of 530 basis points in the DNB model in 2015 should not be changed.

Sensitivity analyses absolute shocks per credit rating; VEV outcomes and historical back-tests			
Absolute shock credit spread in basis points	# of exceptions back-test	Kupiec's test value (T=5.024)	Amount of VEV (x1000 mln) DNB model 2015 based on average pension fund
Shock AAA	Weight AAA in portfolio 45%		
60 bps (DNB 2015)	2	2.4	37.9
30 bps	7	0.7	29.2
25 bps	8	1.6	27.8
20 bps	14	11.3	26.4
0 bps	74	288.8	20.6
Shock AA	Weight AA in portfolio 22%		
85 bps	3	1	38.2
80 bps (DNB 2015)	5	0	37.9
75 bps	10	4	37.6
70 bps	11	5.5	37.4
Shock A	Weight A in portfolio 10%		
160 bps	6	0.2	38.8
140 bps	10	4	38.2
130 bps (DNB 2015)	10	4	37.9
120 bps	11	5.5	37.6
Shock BBB	Weight BBB in portfolio 13%		
300 bps	6	0.2	43.4
270 bps	8	1.6	42.0
250 bps	10	4	41.1
240 bps	11	5.5	40.7
180 bps (DNB 2015)	23	35.9	37.9
Shock <BBB	Weight <BBB in portfolio 7%		
630 bps			38.7
530 bps (DNB 2015)			37.9
430 bps			37.1

Table 7.3: Sensitivity analysis absolute shocks per credit rating

7.2.4 Alternative calculation of tracking error based on historical Z-scores

The calculated amount of VEV for active investment risk for the DNB model in 2015 in this research is based on Table 4.5[59], which shows the average tracking error per pension fund and the correction for investment costs. Another method to determine active investment risk is a calculation based on Z-scores. On the Dutch website pensioenfederatie.nl there is an overview of yearly Z-scores from 1998 till 2011 for 48 industry pension funds. A Z-score is the difference between the performance of pension funds and their predetermined related benchmarks. This score can change rapidly per year and per pension fund by for example adjustments in the asset mix of a pension fund without adjusting benchmarks[60]. This means that it is a rough estimation of the performance of a pension fund. Multiplying the standard deviation of this score based on years 1998-2011 by 1.96 results in an estimation of the historical 97.5% tracking-error of a pension fund. From the sample of 48 pension funds the lowest and highest estimated tracking errors are respectively 0.81% and 3.89%. To

[59] Table 4.5 is retrieved from: Herziening berekeningssystemathiek VEV, p.13
[60] www.pensioenfederatie.nl/services/kerncijfers/z-scores_en_performancetoetsen

calculate the tracking error per synthetic pension fund, the pension funds are divided into three groups with ranges close to the tracking errors in Table 4.5, because the highest tracking error is 3.89% the range of the high risk pension fund begins at 3.5 to be able to calculate the average tracking error for this fund.

Tracking error DNB model 2015		Alternative tracking error based on years 1998-2011		
Pension fund	Corrected tracking error Table 4.5	Range alternative tracking errors	Average tracking error in range	Number of funds in range
Low risk	1.5	0<TE<2	1.46	28
Moderate risk	3.5	2<TE<3.5	2.53	17
High risk	6	3.5<TE<6	3.77	3

Table 6.12 Comparing current tracking error with alternative tracking error based on Z-scores 1998-2011

Comparing current tracking errors with alternative tracking errors
Table 6.12 shows the comparison with the tracking errors in the DNB model in 2015 with the alternative tracking errors based on Z-scores from years 1998-2011. Most of the tracking errors based on Z-scores related to the low risk pension fund. The average of this fund is close to the average of the DNB model in 2015. Pension funds with tracking errors related to the high risk fund have an average tracking error of 3.77, which is relatively low compared with the value of the high risk pension fund in the DNB model. As explained earlier the amount of VEV for active investment risk in the DNB model is calculated by multiplying the tracking error with the weight of equity in the asset mix. The Z-scores are based on the total portfolio of a pension fund and the alternative tracking error should therefore be multiplied by the weight of the total portfolio to get a value of VEV for active investment risk. Although the alternative tracking error is often lower than in the DNB model, the amount of VEV for active investment risk with the alternative calculation is most likely higher than in the DNB model, because of the multiplication of the tracking error with the weight of the total portfolio.

7.3 Adding risk factors to the model

Vega risk for options
The shocks for risk factors in the standard model are based on the assumption that returns follow a normal distribution. However for options this is not the case. The historical simulation method in RiskMetrics provides an extra risk factor called Vega risk. Vega risk is determined by the sensitivity of the volatility of the underlying asset of the option. For pension funds with a large number of options in their portfolio the exposure to Vega risk can be significant and a pension fund should include this factor to the calculation of total VEV.

One of the constraints in paragraph 7.1 is that extra risk factors can only be added to the total VEV of the standard model and should not be put into the square root formula. Pension funds do not have to show full cohesion of risk factors of the standard model and extra risk factors. However correlations between risk factors are taken into account in the VaR model in RiskMetrics, where Vega risk shows a high positive correlation with interest rate risk (0.65) and a small positive correlation with equity risk (0.32) and credit risk (0.27) based on years 1998-2013.

8 Conclusions

In this section the answer to the main research question is presented. This is done by comparing the DNB model. The results of this comparison are presented in the main conclusions and the validation of both models. In addition suggestions for further research are presented.

Main research question

- Is the DNB model for calculation of VEV sufficient compared with a historical 97.5% VaR model or to which extension should it be replaced by a partial internal model?

Statistical method

The current DNB model and the DNB model in 2015 were tested using a historical 97.5% VaR method, which is based on 10-day returns between 7-18-1997 and 5-31-2013. When the result of the DNB model is outside the confidence interval of the 97.5% VaR model, the null hypothesis is rejected.

H_0: Value of VEV DNB model is in non-rejection region of the 97.5% VaR model
H_1: Value of VEV DNB model is outside non-rejection region of 97.5% VaR model

Main conclusions: When is the result of the DNB model outside the confidence interval of the 97.5% VaR model?

Six synthetic pension funds and the average pension fund in the Netherlands	Non-rejection region 97.5% VaR model		VEV DNB model (in billion Euros; in %)			
	VEV in bln Euros	VEV in %	Accepted		Rejected	
			Current model		Model 2015	
1: High risk asset mix; 25% interest hedge ratio	219-375	23%-40%	169	18%	207	22%
2: High risk asset mix; 50% interest hedge ratio	149-261	16%-28%	153	16%	188	20%
3: Moderate risk asset mix; 50% interest hedge ratio	155-277	16%-29%	126	13%	166	18%
4: Moderate risk asset mix; 75% interest hedge ratio	99-184	10%-19%	109	12%	151	16%
5: Low risk asset mix; 75% interest hedge ratio	108-166	11%-18%	83	9%	123	13%
6: Low risk asset mix; 100% interest hedge ratio	55-99	6%-10%	71	8%	113	12%
7: Average Dutch fund; 40% interest hedge ratio	180-311	19%-33%	141	15%	181	19%

Table 8.1: Comparing VEV of DNB models with non-rejection/rejection region of the 97.5% VaR model

- **Interest rate risk:** For pension funds with low interest hedge ratios and a high duration gap between fixed assets and liabilities the DNB model does not give a good representation of the amount of interest rate risk. The VEV for interest rate risk is outside the confidence interval of the 97.5% VaR model based on historical returns of the euro swap rates of the most recent 16 years and therefore the null hypothesis is rejected. The risk for interest risk in the DNB model is based on the assumption that the returns of the *euro swap rates* are distributed normally. Back-tests of returns of euro swap rates in recent years show that these returns have high volatility and do not follow a normal distribution, especially for short term interest rates (1-10 years). This leads to high 97.5% VaR levels and the rejection of the DNB models for high risk pension funds.

- **Credit risk:** Based on back-tests of relative (current model) shocks of credit spreads the VEV for credit risk as result of the current DNB model is outside the non-rejection region of the 97.5% VaR model and therefore the null hypothesis is rejected. Based on back-tests of the absolute shocks per credit rating which will be used in the DNB model in 2015; the amount of VEV is above the high boarder of the non-rejection region of the 97.5% VaR model and therefore the null hypothesis is rejected as well. This means that the DNB model that will be implemented in 2015 seems to overestimate credit risk; this is especially the case for AAA rated assets. Pension funds with a large amount of fixed assets in this rating category should consider an internal model for the calculation of credit risk.

- **Positions with non-normal returns:** The DNB model gives a good representation of the risk related to positions with returns that follow the normal distribution. Pension funds with a large weight of positions in their asset mix that have other return distributions should consider changing to an internal model. For the following positions the estimation of risk by the DNB model is not accurate:
    - **Options:** Pension funds with a large number of options in their portfolio should add Vega risk as an extra risk factor to the model.
    - **Investments in private equity:** The valuation of private equity often is based on quarterly figures, this means that returns of these positions have low volatility for large periods of time and have a high volatility for short periods of time. The shocks of the DNB model do not give a good estimation of this pattern of returns.
    - **Investments in direct real estate:** Valuation of direct real estate does not happen frequently and therefore returns of investments in real estate are hard to predict. The DNB shock for direct real estate is a rough estimate. Besides that based on this research correlations between real estate risk and other equity types, based on historical period 1997-2013, are significantly smaller than the 0.75 correlation factors of the DNB model. Pension funds with a large weight of real estate in their portfolio should consider using an internal model to measure these correlations.

Model validation: Strengths and weaknesses of the DNB model and the 97% historical VaR model

	Strengths	Weaknesses
DNB model	• Simplicity; calculation method is relative simple, because of predetermined parameters and correlations • Generalization; the model is applicable for a large number of pension funds	• Assumption of normality market returns; model only gives good estimation for linear instruments that follow normal distribution • Parameters and correlations in the DNB model are fixed and can deviate from real values of market variables • Parameters should be updated frequently to adjust to changes market variables
Historical 97.5% VaR model	• Model is based on real market returns and therefore gives a realistic estimate of movements of market variables(no assumption of distribution) • Takes into account real correlations between positions • Options for VaR model can be changed relatively easy (confidence level, look-back period, return horizon) • Output of simulated returns gives information about the losses that occur in the tail of the profit/loss distribution	• Result depends strongly on options chosen (historical time period, return horizon) • Can only measure risk factors which have historical data (S6 and S7 cannot be measured) • Yearly VaR based on 10-day returns using the square root rule[61] leads to an estimation error, however the square root rule is commonly accepted • The result of the VaR depends on choice of input positions for groups of pension funds • Input of positions in model is time-consuming

Table 8.2: Strengths and weaknesses of the DNB model and the 97.5% historical VaR model

Suggestions for further research

In this research the risk factors of the DNB model that are considered to be zero, and therefore are not taken into account for the calculation of VEV, are not taken into account because the limited amount of time available. However, pension funds must be able to quantify these risk factors. More research can be done for the following risk factors:

- Alternative calculation for active investment risk (tracking error based on entire portfolio of investments)
- Vega risk
- Liquidity risk
- Operational risk
- Concentration risk

The risk factors Vega risk and Concentration risk are incorporated into the historical VaR model. However because the amount of options in the portfolios of the pension funds that were used in this research was small the VaR for Vega risk was insignificant. Concentration risk relates to the correlations between positions in the portfolio. In the VaR model real correlations between positions in the historical look-back period are taken into account. Although concentration risk is addressed by looking at correlations in this research, the quantification of amount of concentration risk is not visible in this research; therefore more research can be done quantifying this risk factor.

[61] Square root rule: A one-year VaR is calculated by taking a 10-day VaR and multiplying this VaR with $\sqrt{(\frac{10}{264})}$

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Appendix A: Technical background VaR calculations using RiskMetrics Risk Manager: A stepwise approach

This paragraph gives a stepwise approach for the calculation of a VaR according to RiskMetrics Risk manager. This approach shows the underlying assumptions and calculations which are executed by the software programme in three steps.

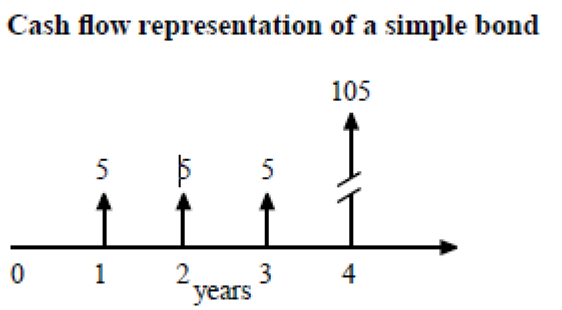
Step 1: Defining VaR parameters

To determine a VaR for a portfolio of assets the first step is to define parameters. These are the VaR forecast horizon, the confidence level, VaR prediction and the lookback-period and the return horizon. These parameters have all been explained in paragraph 3.2.

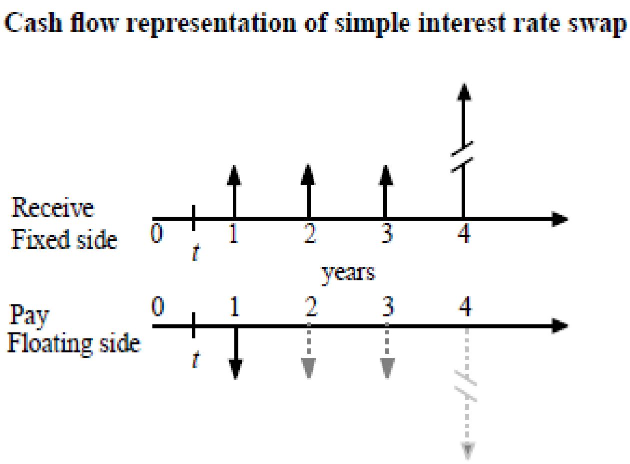
Step 2: Identify exposures and cash flows of positions

The second step is to identify the exposures of all positions in the portfolio. In RiskMetrics this is done by transforming positions into cash flows. Cash flows are defined by an amount of a currency, a payment date and the credit standing of the payor.[62] These cash flows are market-to-market, which means that they are determined using current market prices and rates. A description of expressing positions in fixed income and foreign exchange instruments in terms of cash flows follows now.

Fixed income: Fixed income securities can be easily represented as cash flows given their standard future stream of payments. In practice, this is equivalent to decomposing a bond into a stream of zero-coupon instruments, as can be seen in the cash flow representation of a simple bond. Bonds are exposed to interest rate risk and credit risk and to currency risk if the bond currency is another currency then the base currency of a portfolio.



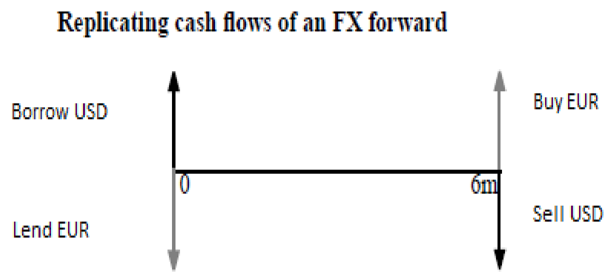
Simple bond: This chart represents a bond with a par value of 100, a maturity of 4 years and a coupon rate of 5%. We can represent the cash flows of the simple bond in this example as cash flows from four zero coupon bonds with maturities of 1, 2, 3 and 4 years. This implies that on a risk basis, there is no difference between holding the simple bond or the corresponding four zero-coupon bonds.[63]



Interest rate swap: Investors enter into interest-rate swaps to change their exposure to interest rate uncertainty by exchanging interest flows. In order to understand how to identify a simple interest-rate swap, a swap should be thought of as a portfolio consisting of one fixed and one floating rate instrument. The cash flows on the fixed side are simply the fixed coupon payments over

[63] Risk metrics technical document 1996 p.109

the next 4 years. The cash flows of the floating side are negative based on a floating rate that is set some time in advance of the actual coupon payment. For example, if coupon payments are paid on an annual basis, the 1-year LIBOR rate would be used to determine the payment in 1 years' time.[64]



Foreign Exchange Forward: A foreign exchange (FX) forward is an agreement to exchange at a future date, an amount of one currency for another at a specified forward rate. They are used to hedge currency risk. Mapping a forward foreign exchange position is facilitated by the ability to express the forward as a function of two interest rates and a spot foreign exchange rate. For example, the chart above shows the cash flows of an FX forward that allows an investor to buy Euros with US dollars in 6 months' time at a pre-specified forward rate.[65]

Equity: Positions in equity endure equity risk which is the risk based on decreases of equity returns. Equity positions held in foreign countries are subject to foreign exchange risk in addition to the risk from holding equity.[66]

Commodities: Exposures to commodities can be explained using a framework similar to that of interest rates. Risks arise in both the spot market (you purchase a product today and store it over time) and from transactions that take place in the future (e.g., physical delivery of a product in one month's time).[67]

Step 3: Two methods to calculate VaR

After all positions are transformed into cash flows and the cash flows are mapped the calculation of VaR can be done. As mentioned earlier RiskMetrics provides three methods for this calculation: the parametric VaR calculation, a calculation based on historical simulation and a calculation using Monte Carlo simulation. In this step the underlying calculations of the historical simulation and the parametric method are explained. As explained earlier Monte Carlo simulation is not used in this research, because there is enough historical data to test the parameters using historical simulation. Therefore the Monte Carlo simulation method is not explained in this paragraph.

Parametric VaR calculation method

All the examples mentioned in step 2 are linear instruments. The parametric VaR calculation method can be used for these instruments. In this section the general formula to compute VaR for linear instruments is provided. Consider a portfolio that consists of N positions and that each of the positions consists of one cash flow on which we have volatility and correlation forecasts. Denote the relative change in value of the nth position by $\delta_n r_{n,t}$. We can write the change in value of the portfolio, $r_{p,t}$, as

$r_{p,t} = \sum_{n=1}^{N} w_n * \delta_n * r_{n,t}$, where w_n is the total amount invested in the *n*th position.

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[64] Risk metrics technical document 1996 p.109
[65] Risk metrics technical document 1996 p.115
[66] Risk metrics technical document 1996 p.116
[67] Risk metrics technical document 1996 p.117

For example, suppose that the total current market value of a portfolio is $100 and that $10 is allocated to the first position. It follows that w_1= $10.

Now, suppose that the VaR forecast horizon is one day. In RiskMetrics, the 95% VaR on a portfolio of simple linear instruments can be computed by 1.65 times the standard deviation of $r_{p,t}$, the portfolio return, one day ahead. The 1.65 multiplication factor relates to a 95% confidence level, for a 97.5% VaR the factor is 1.96. According to Morgan & Reuters[68] the expression of VaR is given as follows:

$VaR_t = \sqrt{\sigma_{t|t-1} * \ R_{t|t-1} * \sigma_{t|t-1}^T}$ where

$\sigma_{t|t-1} = [1.65\sigma_{1|t-1}w_1\delta_1 \quad 1.65\sigma_{2|t-1}w_2\delta_2 \ldots \quad 1.65\sigma_{N|t-1}w_N\delta_N]$ is the individual VaR vector (1*N) and

$$R_{t|t-1} = \begin{bmatrix} 1 & \rho_{12,t|t-1} & \cdots & \rho_{1N,t|t-1} \\ \rho_{21,t|t-1} & 1 & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ \rho_{N1,t|t-1} & \cdots & \cdots & 1 \end{bmatrix}$$

is the correlation matrix of the returns on the underlying cash flows. The above computations are for portfolios whose returns are assumed to follow a conditional normal distribution.[69]

Historical Simulation method

The Historical Simulation method estimates VaR by taking actual historical rates and revalues every position for each change in market rates (i.e. each trial) according to user-specified start and end dates. There are no assumptions about normality or otherwise. Instead, distributions of underlying risk factors are taken exactly as found over the specified historical time period, the so-called lookback-period.

This method accurately prices all types of complex non-linear positions as well as simple linear instruments. It also provides a full distribution of potential portfolio gains and losses (which need not be symmetrical). If the underlying risk factors exhibit non-normal behavior such as fat-tails or mean-reversion, then the resulting VaR will include these effects. However, tail risk can only be examined if the historical data set includes tail events. That's why sampling history requires care in selection. Market conditions and currency devaluations may have occurred in the lookback-period, which led to dramatically shifting time series relationships.[70]

[68] Risk metrics technical document 1996 p.126
[69] Risk metrics technical document 1996 p.126
[70] Risk methodologies from:http://help.riskmetrics.com/RiskManager3,

Appendix B: Asset type by position average pension fund NL

Commodity	**1,473,975**
Dow jones UBS commodity TR index	500,000
Gold	500,000
Schroder AS Commodity I Acc	473,975
Direct real estate	**14,353,900**
Gim Real Estate	4,353,900
Thames River Property Growth & Income Inc EUR A in EUR	5,000,000
UBS (D) Euroinvest Immobilien in EUR	5,000,000
Equity emerging markets	**55,859,366**
Aberdeen Global - Emerging Mkts Equity I2 USD	16,006,127
Banco do Brasil Ord Shs	1,900,474
Cash equity bank account BRL	1,621,281
Cash equity bank account HKD	97,489
Cash equity bank account INR	69,186
Cash equity bank account PLN	521,956
Morgan Stanley Emerging Markets Fund Inc	19,661,870
Morgan Stanley Emerging Markets Equity I EUR in EUR	8,064,614
PGE Polska Grupa Energetyczna Ord Shs	1,148,748
Petrochina Ord Shs H	6,767,621
Indirect real estate (counted as equity mature markets in models)	**68,284,730**
British Land REIT	2,841,758
CBRE Clarion Global Real Estate Income Fund	10,132,630
Corio REIT	3,636,704
Deutsche Wohnen Ord Shs	1,705,200
Morgan Stanley Global Property I USD	39,731,595
Schroder Indirect Real Estate A	3,454,334
Swiss Prime Site Ord Shs	1,803,858
Unibail Rodamco REIT	2,336,850
Wereldhave NV	2,641,802
Other investments	**-9,883,217**
Cash bank account EUR other investments	2,663,902
Cash bank account USD other investments	-794,575
Cash	-12,500,000
GMO Trust: GMO Alpha Only Fund; Class IV Shares	747,455
Private equity	**67,071,776**
BlackRock Global Funds; BGF Global Opportunities Fund A2 USD in USD	10,000,000
Pioneer Funds US Pioneer Fund H Hedge No Dis EUR in EUR	6,826,456
Quantitative Group of Funds: Long/Short Fund; Institutional Shares	9,503,647
Venture capital Europe	14,839,919
Venture capital fund US	25,901,754
SWAP IRS (counted as fixed asset in models)	**4,554,125**
Interest rate swap 2045	4,554,125
Equity mature markets	**198,906,549**
ASML Holding Ord Shs	8,534,064
Aberdeen Global II - Euro Corporate Bond Z2 EUR	19,660,320
Acadian Global Equity A	5,569,668
Akzo Nobel Ord Shs	4,511,872

Apple Ord Shs	6,942,790
ArcelorMittal Ord Shs	2,865,892
BHP Billiton Ord Shs	8,139,151
Boeing Ord Shs	3,784,005
Call wolters kluwer nv 16 2014	-1,796,411
Cash equity bank account AUD	212,001
Cash equity bank account GBP	98,402
Cash equity bank account JPY	-3,276
Cash equity bank account SEK	-90,287
Cash equity bank account usd	-9,603,975
Citigroup Ord Shs	1,101,883
Coca-Cola Ord Shs	1,200,039
Commerzbank Ag	6,260,589
Deutsche Bank AG (London Branch) Call 0 INR HOUS DEV FIN-A 30Jan17	114,638
Electrolux B Ord Shs	774,376
Equity blackrock fund	4,421,688
Exxon Mobil Ord Shs	7,407,102
Google Ord Shs Class A	7,028,730
ING Groep GDR	275,781
KAS BANK GDR	272,916
Kellogg Ord Shs	1,172,960
Koninklijke Ahold Ord Shs	2,305,307
Macys Ord Shs	557,894
Merck & Co Ord Shs	6,446,808
Microsoft Ord Shs	8,103,671
Mitsubishi UFJ Financial Group Ord Shs	9,158,652
NP STL & SMTM ML Ord Shs	8,312,516
Nestle Ord Shs	7,773,500
Nissan Motor Ord Shs	7,599,892
Procter & Gamble Ord Shs	11,816,846
Put Cisco systems inc 17.5 Jan 2013	58,185
Royal Dutch Shell Ord Shs Class A	2,940,862
Tata Steel Ord Shs	3,229,983
Telecom Italia Ord Shs	2,749,280
Transcanada Ord Shs	1,116,820
Unilever GDR	5,224,325
Unilever Ord Shs	13,955,188
Vodafone Group ADR Reptg 10 Ord Shs	863,174
Volvo Ord Shs	8,549,343
Westpac Banking Corporation Ord Shs	5,824,551
iShares Euro STOXX 50 EUR UCITS ETF	13,464,836
Fixed income assets	**501,713,363**
ABN AMRO BANK NV 3.5 01/18/2022	5,639,937
AKZO NOBEL SWEDEN FINANCE AB 2.625 07/27/2022	2,835,504
ARCELORMITTAL 7.5 10/15/2039	243,365
ATLANTEO CAPITAL LTD 8.12 11/20/2041	119,821
BANCO COMERCIAL PORTUGUES SA 10 03/03/2015	25,788,835
BANCO NACIONAL DE DESENVOLVIMENTO ECONOMICO E SOCIAL 6.369 06/16/2018	2,423,105
BANK NEDERLANDSE GEMEENTEN NV 3.75 01/14/2020	2,186,549

BELGIUM, KINGDOM OF (GOVERNMENT) 4.25 09/28/2022	8,069,327
BNP PARIBAS HOME LOAN SFH 2.2 11/02/2015	4,794,524
Blackrock Ins EUR Liq Agy Inc	1,000,000
COCA-COLA HBC FINANCE BV 7.875 01/15/2014	513,320
COMMONWEALTH BANK OF AUSTRALIA 4.25 04/06/2018	1,064,575
Cash compensatie interest rate swap	-14,000,000
Cash currency overlay bank account eur	606,882
Cash fixed income bank account EUR	35,000,000
Cash fixed income bank account GBP	1,520
Cash swap overlay	3,640,003
DECO 14 PAN EUROPE 5 BV 0.805 01/27/2014	7,024,340
DEPFA ACS BANK 3.875 07/15/2013	2,867,897
DEUTSCHE TELEKOM INTERNATIONAL FINANCE BV 6 01/20/2017	1,246,276
ENI SPA 4.25 02/03/2020	14,084,222
FMS WERTMANAGEMENT ANSTALT DES OEFFENTLICHEN RECHTS 1.875 05/09/2019	773,332
FRANCE, REPUBLIC OF (GOVERNMENT) 3.5 04/25/2015	13,988,443
FRANCE, REPUBLIC OF (GOVERNMENT) 4.5 04/25/2041	5,286,674
FX Forward EUR/AUD	0
FX Forward EUR/BRL	0
FX Forward EUR/CHF	-82
FX Forward EUR/GBP	0
FX Forward EUR/HKD	0
FX Forward EUR/INR	0
FX Forward EUR/JPY	0
FX Forward EUR/PLN	0
FX Forward EUR/SEK	0
FX Forward EUR/USD	0
FX Forward EUR/USD 31-7-2013	0
GERMANY (GOVERNMENT OF) 3.5 10/22/2053	4,591,059
GERMANY (GOVERNMENT OF) 4.75 07/04/2034	49,293,428
GERMANY (GOVERNMENT OF) 4.75 07/04/2040	10,131,176
GERMANY (GOVERNMENT OF) STRIP 07/04/2034	21,391,488
ING Funds Trust: ING High Yield Bond Fund; Class A Shares	15,146,495
ITALY, REPUBLIC OF (GOVERNMENT) 5 03/01/2022	13,725,160
LEASEPLAN CORP NV 4.125 01/13/2015	437,335
LOCAT SECURITISATION VEHICLE 3 SRL 0.868 12/20/2026	19,066,515
MEXICO (UNITED MEXICAN STATES) (GOVERNMENT) 5.95 03/19/2019	2,805,810
MGM RESORTS INTERNATIONAL 7.625 01/15/2017	3,417,036
NESTLE FINANCE INTERNATIONAL LTD 1.75 09/12/2022	39,779
NETHERLANDS, KINGDOM OF (GOVERNMENT) 3.75 01/15/2042	32,999,980
NETHERLANDS, KINGDOM OF (GOVERNMENT) 7.5 01/15/2023	73,519,111
PETROBRAS INTERNATIONAL FINANCE CO 5.375 01/27/2021	5,148,322
POLAND, REPUBLIC OF (GOVERNMENT) 5.625 06/20/2018	4,583,676
RABOBANK NEDERLAND NV 3.875 04/20/2016	8,540,677
Robeco High Yield Bonds I USD	1,000,000
SHELL INTERNATIONAL FINANCE BV 4.375 05/14/2018	6,253,614
SINOCHEM OVERSEAS CAPITAL CO LTD 4.5 11/12/2020	3,561,255
SLM STUDENT LOAN TRUST 2003-5 1.146 06/17/2024	7,855,503
SLOVAK REPUBLIC (GOVERNMENT) 4.35 10/14/2025	15,711,905
SPAIN, KINGDOM OF (GOVERNMENT) 5.9 07/30/2026	20,027,711

SUEZ ENVIRONNEMENT CO SA 4.82 PERP	656,372
SVENSK EXPORTKREDIT AB 15 03/27/2037	4,468,233
SWITZERLAND, CONFEDERATION OF (GOVERNMENT) 3.75 06/10/2015	5,529,881
Schroder ISF Global Conv Bond EUR Hdg A Acc	789,127
TURKEY, REPUBLIC OF (GOVERNMENT) 10 06/17/2015	834,002
UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND (GOVERNMENT) 3.4 07/25/2029	1,972,971
UNITED STATES STEEL CORP 7.5 03/15/2022	1,145,777
UNITED STATES TREASURY 3.5 06/28/2017	33,000,000
UNITED STATES TREASURY 6.164 05/02/2035	5,000,000
VATTENFALL AB 5.25 03/17/2016	1,063,259
VODAFONE GROUP PLC 4.65 01/20/2022	952,412
VOLKSWAGEN LEASING GMBH 2.25 11/10/2014	1,855,921

Appendix C: VEV levels pension funds in the Netherlands

Annual reports 2011	VEV level[71]	Clients K A S B A N K 12-31-2012	VEV level
Philips	108.00%	Atos	107.88%
Rabobank	109.60%	RBS	108.34%
Beroepsvervoer	111.10%	Randstad	110.59%
ING	111.70%	Gasunie	110.61%
KPN	111.80%	Notarieel	111.48%
Ahold	112.10%	Dranken	111.60%
UWV	112.80%	van Lanschot	111.87%
Glasfabrieken	113.80%	Detailhandel	112.10%
ABN Amro	114.00%	TNO	112.28%
Akzo Nobel	114.10%	SANOMA	112.29%
DSM	114.10%	AXA	112.34%
ACF brocacef	114.60%	Vlakglas	112.70%
Hoogovens	114.90%	KASBANK	112.75%
Alcatel-Lucent	114.97%	SPOA	112.82%
Grolsch	115.30%	SPEO	113.04%
Metalektro	115.30%	AVH	113.28%
KLM Algemeen	117.00%	WK	113.30%
Landbouw	117.00%	Levensmiddelen	113.42%
Grafische bedrijven	117.00%	Xerox	113.60%
Metro	117.00%	R&B	114.40%
Bouwnijverheid	117.70%	Verf en Druk	114.41%
SPWoningcorporaties	117.80%	POB	114.86%
SPA	118.20%	Staples	115.00%
Architecten	118.20%	Thales	115.84%
KLM Vliegend Personeel	118.30%	Slagers	116.20%
KLM Cabinepersoneel	119.90%	Telegraaf	116.31%
Huisartsen	120.40%	Anwb	116.47%
Spoorwegen	121.00%	Alliance	116.70%
Holland Casino	121.50%	Q8	118.12%
Heineken	121.80%	PMA	127.93%
Kunstenaars	122%		
Metaal en Techniek	122.10%		
Zorg en Welzijn	122.80%		
Medisch specialisten	122.88%		
ABP	123.90%		
Shell	125.00%		
Waterbouw	130%		

[71] Based on annual reports pension funds 2011

Appendix D: Example Kupiec's test

Variable in test	Explanation variable	Value of variable in chapter 5
T	Total number of returns used for the back-test	T=415 10day-returns
X	Number of exceptions (An exception occurs when a return is smaller than the 97.5% VaR level)	
T-x	number of 10day-returns that do not count as an exception	
x/T	Percentage of exceptions	For a 97.5% VaR level x/T =0.025; x=0.025*415=10
p	Chance related to confidence level of the VaR model	For 97.5% confidence level p=0.025

Formula test value:

$$LR_{POF} = -2ln\left(\frac{(1-p)^{T-x}p^x}{\left[1-\left(\frac{x}{T}\right)\right]^{T-x}\left(\frac{x}{T}\right)^x}\right)$$

LR_{POF} is chi-square distributed with one degree of freedom. If the test statistic is lower than the critical chi-square value relating to the 97.5% confidence level, the model passes the test. When the value is higher the model is rejected. The critical value is 5.024.

Calculation Kupiecs test (T=415 Critical value =5.024)			
x	T-x	x/T	Test value (LRpof)
1	414	0.00241	14.29
2	413	0.004819	10.34
3	412	0.007229	7.44
4	411	0.009639	5.23
5	410	0.012048	3.52
6	409	0.014458	2.23
7	408	0.016867	1.27
8	407	0.019277	0.60
9	406	0.021687	0.20
10	405	0.024096	0.01
11	404	0.026506	0.04
12	403	0.028916	0.25
13	402	0.031325	0.63
14	401	0.033735	1.17
15	400	0.036145	1.86
16	399	0.038554	2.69
17	398	0.040964	3.65
18	397	0.043373	4.73
19	396	0.045783	5.93
20	395	0.048193	7.23
21	394	0.050602	8.65
22	393	0.053012	10.16
23	392	0.055422	11.77
24	391	0.057831	13.47
25	390	0.060241	15.26

Table calculation test values