CEIOPS' Advice for Level 2 Implementing Measures on Solvency II:

SCR STANDARD FORMULA

Article 111(d)

Correlations

(former Consultation Paper 74)

Table of content

1. Introduction

1.1. In its letter of 19 July 2007, the European Commission requested CEIOPS to provide final, fully consulted advice on Level 2 implementing measures by October 2009 and recommended CEIOPS to develop Level 3 guidance on certain areas to foster supervisory convergence. On 12 June 2009 the European Commission sent a letter with further guidance regarding the Solvency II project, including the list of implementing measures and timetable until implementation.[1]

1.2. This Paper aims at providing advice with regard to the choice of the correlation parameters applied in the SCR standard formula to aggregate capital requirements on module and sub-module level as requested in Article 111d of the Solvency II Level 1 text ("Level 1 text"). [2]

2. Extract from Level 1 Text

2.1 Legal basis for implementing measure

Article 111 - Implementing measures

1.   In order to ensure that the same treatment is applied to all insurance and reinsurance undertakings calculating the Solvency Capital Requirement on the basis of the standard formula, or to take account of market developments, the Commission shall adopt implementing measures laying down the following:

[…]

(c)   the correlation parameters, including, if necessary, those set out in Annex IV, and the procedures for the updating of those parameters;

[…]

2.2 Other relevant Level 1 text for providing the background to the advice

Article 101 - Calculation of the Solvency Capital Requirement
[…]
3.   The Solvency Capital Requirement shall be calibrated so as to ensure that all quantifiable risks to which an insurance or reinsurance undertaking is exposed are taken into account. It shall cover existing business, as well as

---

the new business expected to be written over the next twelve months. With respect to existing business, it shall cover unexpected losses only.
It shall correspond to the Value-at-Risk of the basic own funds of an insurance or reinsurance undertaking subject to a confidence level of 99.5% over a one-year period.

Article 104 - Design of the Basic Solvency Capital Requirement
[…]
3.   The correlation coefficients for the aggregation of the risk modules referred to in paragraph 1, as well as the calibration of the capital requirements for each risk module, shall result in an overall Solvency Capital Requirement which complies with the principles set out in Article 101.

ANNEX IV - Solvency Capital Requirement (SCR) standard formula

1. *Calculation of the Basic Solvency Capital Requirement*

   The Basic Solvency Capital Requirement set out in Article 104(1) shall be equal to the following:[3]

$$Basic\ SCR = \sqrt{\sum \sum_{i,j} Corr_{i,j} \times SCR_i \times SCR_j}$$

   where SCRi denotes the risk module i and SCRj denotes the risk module j, and where "i,j" means that the sum of the different terms should cover all possible combinations of i and j. In the calculation, SCRi and SCRj are replaced by the following:

   – SCR non-life denotes the non-life underwriting risk module;
   – SCR life denotes the life underwriting risk module;
   – SCR health denotes the health underwriting risk module;
   – SCR market denotes the market risk module;
   – SCR default denotes the counterparty default risk module.

   The factor Corr i,j denotes the item set out in row i and in column j of the following correlation matrix:

i \ j	Market	Default	Life	Health	Non-life
Market	1	0.25	0.25	0.25	0.25
Default	0.25	1	0.25	0.25	0.5
Life	0.25	0.25	1	0.25	0

---

[3] CEIOPS remark: The first summation sign under the square root appears to be a printing error.

Health	0.25	0.25	0.25	1	0
Non-life	0.25	0.5	0	0	1

2. Calculation of the non-life underwriting risk module

The non-life underwriting risk module set out in Article 105(2) shall be equal to the following:

$$SCR_{non-life} = \sqrt{\sum_{i,j} Corr_{i,j} \times SCR_i \times SCR_j}$$

where SCRi denotes the sub-module i and SCRj denotes the sub-module j, and where "i,j" means that the sum of the different terms should cover all possible combinations of i and j. In the calculation, SCRi and SCRj are replaced by the following:

- – *SCR nl premium and reserve denotes the non-life premium and reserve risk sub-module;*
- – *SCR nl catastrophe denotes the non-life catastrophe risk sub-module.*

3. Calculation of the life underwriting risk module

The life underwriting risk module set out in Article 105(3) shall be equal to the following:

$$SCR_{life} = \sqrt{\sum_{i,j} Corr_{i,j} \times SCR_i \times SCR_j}$$

where SCRi denotes the sub-module i and SCRj denotes the sub-module j, and where "i,j" means that the sum of the different terms should cover all possible combinations of i and j. In the calculation, SCRi and SCRj are replaced by the following:

- – SCR mortality denotes the mortality risk sub-module;
- – SCR longevity denotes the longevity risk sub-module;
- – SCR disability denotes the disability - morbidity risk sub-module;
- – SCR life expense denotes the life expense risk sub-module;
- – SCR revision denotes the revision risk sub-module;
- – SCR lapse denotes the lapse risk sub-module;
- – SCR life catastrophe denotes the life catastrophe risk sub-module.

4. Calculation of the market risk module

Structure of the market risk module
The market risk module, set out in Article 105(5) shall be equal to the following:

$$SCR_{market} = \sqrt{\sum_{i,j} Corr_{i,j} \times SCR_i \times SCR_j}$$

where SCRi denotes the sub-module i and SCRj denotes the sub-module j, and where "i,j" means that the sum of the different terms should cover all possible combinations of i and j. In the calculation, SCRi and SCRj are replaced by the following:

- SCR interest rate denotes the interest rate risk sub-module;
- SCR equity denotes the equity risk sub-module;
- SCR property denotes the property risk sub-module;
- SCR spread denotes the spread risk sub-module;
- SCR concentration denotes the market risk concentrations sub-module;
- SCR currency denotes the currency risk sub-module.

3. Advice

3.1. Explanatory text

3.1.1. Previous advice

3.1.   In its "Further advice to the European Commission on Pillar 1 issues" (CEIOPS–DOC–08/07, March 2007)[4], further elaborating on its previous advice to the tenth Call for Advice from the Commission, CEIOPS recommended the use of correlation matrices for the aggregation of capital requirements. As to the choice of the correlation parameters the following safeguards were stated to be important:

- "to keep note of any dependencies that would not be addressed properly by this treatment;" i.e. by linear correlations,

- "to choose the correlation coefficients to adequately reflect potential dependencies in the tail of the distributions;"

- "to assess the stability of any correlation assumptions under stress conditions".

3.1.2. Background

3.2.   The SCR standard formula as defined in the Level 1 text follows a modular approach. The overall risk which the insurance or reinsurance undertaking is exposed to is divided into sub-risks. For each sub-risk a capital requirement $SCR_{sub-risk}$ is determined. The capital requirements on sub-risk level are aggregated in order to derive the capital requirement for the overall risk.

3.3.   A simple technique to aggregate capital requirements is the use of correlation matrices. The capital requirement for the overall risk is calculated as follows:

$$SCR_{overall} = \sqrt{\sum_{i,j} Corr_{i,j} \cdot SCR_i \cdot SCR_j}$$

where i and j run over all sub-risks and $Corr_{i,j}$ denotes the entries of the correlation matrix, i.e. the correlation parameters.

3.4.   According to Articles 104(1) and 105 of the Level 1 text, the aggregation of the capital requirements for the sub-risks of at least the following parts of the standard formula are done by means of correlation matrices:

- the Basic SCR,

- the capital requirement for non-life underwriting risk,

---

[4] See http://www.ceiops.eu/media/files/publications/submissionstotheec/CEIOPS-DOC-08-07AdviceonPillarI-Issues-FurtherAdvice.pdf, paragraph 5.33

- the capital requirement for life underwriting risk, and

- the capital requirement for market risk.

3.5. Moreover, the Level 1 text does not specify the aggregation method for certain other parts of the standard formula, for example for the health underwriting module or regarding any further subdivision of sub-modules for the above mentioned modules. Correlation matrices could also be used for these aggregation tasks.

3.6. The selection of the correlation parameters has a significant influence on the result of the SCR calculation. For example, if five capital requirements of equal size are aggregated, the result is 55% lower if the correlation parameter 0 instead of the parameter 1 is used to describe the relation between each pair of risks. Hence, the choice of correlation parameters has an impact on the level of diversification to be obtained within the SCR standard formula.

3.7. Having regard to the complexity and materiality of setting correlation parameters in the standard formula, CEIOPS will continue to explore this issue in its future technical work.

3.1.3. Mathematical analysis of the aggregation technique

3.8. In the mathematical science, correlation matrices are used to aggregate standard deviations of probability distributions or random variables. In this case, the entries of the matrix are defined as linear correlation coefficients, i.e. for two random variables X and Y, the entry is

$$\rho = \frac{Cov(X,Y)}{\sqrt{Var(X)Var(Y)}}.$$

3.9. The capital requirements that are aggregated in the standard formula are, from a mathematical point of view, not standard deviations but quantiles of probability distributions.[5] However, this does not imply that it is an abuse of the concept of correlation matrices to apply it in the context of the standard formula. This is because it can be shown that for multivariate normal distributions (or more general: for elliptic distributions), the aggregation with correlation matrices produces a correct aggregate of quantiles.[6]

3.10. On the other hand, only for a restricted class of distributions the aggregation with linear correlation coefficients produces the correct result. In the mathematical literature a number of examples can be found where linear correlations in themselves are insufficient to fully reflect the dependence between distributions and where the use of linear correlations

---

[5] The only exception to this rule are the correlation coefficients applied within the premium and reserve risk sub-module of the standard formula (cf. sub-section xxx, below), to which the considerations set out in this sub-section are not intended to apply.
[6] In case the expected values of the marginal distributions are zero. This simplifying assumption is made in the standard formula which intends to quantify unexpected losses.

could lead to incorrect aggregation results, i.e. to either an under- or an over-estimation of the capital requirements at the aggregated level.[7]

3.11. Two main reasons can be identified for this aggregation problem:

- The dependence between the distributions is not linear; for example there are tail dependencies.

- The shape of the marginal distributions is significantly different from the normal distribution; for example the distributions are skewed.

3.12. Unfortunately, both characteristics are shared by many risks which an insurance or reinsurance undertaking is exposed to. Tail dependence exists both in underwriting risks (e.g. catastrophe events) and in market and credit risks. The current financial crisis is a good example of this. Market parameters (like credit spreads, property prices and equity prices) which have revealed no strong dependence under benign economic conditions simultaneously showed strong adverse changes in the last two years. Moreover, it became apparent that a change in one parameter had a reinforcing effect on the deterioration of the other parameters.

3.13. As to the second characteristic, it is known of the relevant risks of an insurance or reinsurance undertaking that the underlying distributions are not normal. They are usually skewed and some of them are truncated by reinsurance or hedging.

3.14. Because of these shortfalls of the correlation technique and the relevance of the shortfalls to the risks covered in the standard formula, the choice of the correlation factors should attempt to avoid misestimating the aggregate risk. In particular, linear correlations are in many cases not an appropriate choice for the correlation parameter.

3.15. Instead, the correlation parameters should be chosen in such a way as to achieve the best approximation of the 99.5% VaR for the aggregated capital requirement. In mathematical terms, this approach can be described as follows: for two risks X and Y with $E(X)=E(Y)=0$, the correlation parameter ρ should minimise the aggregation error

$$\left| VaR(X+Y)^2 - VaR(X)^2 - VaR(Y)^2 - 2\rho \cdot VaR(X) \cdot VaR(Y) \right|.$$

3.16. This approach is a consequence of Article 104 of the Level 1 text. According to paragraph 3 of Article 104,

---

[7] See for example: P. Embrechts, A. McNeil, D. Strautmann: "Correlation and Dependence in Risk Managemement: Properties and Pitfalls" (2002) In: Risk Management: Value at Risk and Beyond, ed. M.A.H. Dempster, Cambridge University Press, Cambridge, pp. 176-223 (http://www.math.ethz.ch/~strauman/preprints/pitfalls.pdf). The authors provide a general analysis of the problems connected with linear correlations.
D. Pfeifer, D. Straßburger: "Solvency II: Stability problems with the SCR aggregation formula", Scandinavian Actuarial Journal (2008), No. 1, pp. 61-77 (http://www.staff.uni-oldenburg.de/dietmar.pfeifer/SCR_Pfeifer_Strassburger.pdf). The authors give examples for beta distributions.
A. Sandström: "Solvency II: Calibration for Skewness", Scandinavian Actuarial Journal (2007), No. 2, pp. 126-134. Sandström discusses a modification of the aggregation method to better allow for skewed distributions.

"the correlation coefficients for the aggregation of the risk modules referred to in paragraph 1, as well as the calibration of the capital requirements for each risk module, shall result in an overall Solvency Capital Requirement which complies with the principles set out in Article 101."

Article 101 stipulates that the SCR corresponds to the Value-at-Risk with a confidence level of 99.5%.

3.17. CEIOPS acknowledges that achieving this overall conceptual aim is likely to present a number of practical challenges:

- In most cases[8] the standard formula does not set out explicit assumptions on the type or shape of the risk distributions of X and Y, nor on the dependence structure between X and Y. In these cases the risk distribution of the aggregated risk X + Y will not generally be known, so that its Value-of-Risk cannot be estimated or observed directly;

- In the scenario-based sub-modules, the standard formula pre-scribes shocks to the underlying risk drivers of the sub-risk considered.[9] The risk variables X and Y – representing the change of the level of own funds of the insurer resulting from a change of the underlying risk driver – then also depend on the risk characteristics of the insurer's individual portfolios. Hence in these cases the relationship between the Value at Risk for the aggregated risk X+Y in respect to the Value at Risk for the individual risks X and Y would likely be different across different insurers: and

- where more than two risks are aggregated, the minimisation of the aggregation error has to go beyond only considering individual pairs of risks.

3.18. As was observed in the above, where it can be assumed that the considered risks follow a multivariate normal (or elliptical) distribution, minimising the aggregation error can be achieved by calibrating the correlation parameters in the standard formula as linear correlations. Hence in this special case, the challenges described above could be met in case linear correlation coefficients can be reliably derived.

3.19. However, where such a simplifying assumption cannot be made – for example, where there is tail-dependency between the risks or where the shape of the marginal risk distributions is significantly different from the normal distribution - the use of linear correlations may not be adequate for the purpose of minimising the aggregation error. In these cases, it may be necessary to consider other dependence concepts for deriving the correlation parameters in the standard formula.

---

[8] With the exception of the premium and reserve risk sub-module, where a lognormal distribution is assumed.
[9] For example, in the interest rate sub-module the underlying risk drivers would be the level and the volatility of the term structure of risk-free interest rates.

3.20. For example, in this case it may be more adequate to derive the standard formula correlation parameter for two risks X and Y as the coefficient of (upper) tail dependence of X any Y, which is defined as:[10]

$$\rho = \lim_{\alpha \to 1-} P\big(Y > F_Y^{-1}(\alpha) \,\big|\, X > F_X^{-1}(\alpha)\big),$$

where F_X and F_Y are the distribution functions of X and Y, respectively. Note that this coefficient measures the asymptotic degree of dependence in the "tail" of the risk distributions of X and Y, i.e. the likelihood of simultaneous occurrences of extreme events in both risks.

3.21. We note that such a use of "tail correlations" has been proposed in the "Global Framework for Insurer Solvency Assessment" of the International Actuarial Association: [11]

"This 'correlation' need not be the standard linear correlation found in statistics text books. In particular, it could be a 'tail correlation' to incorporate the possibility of simultaneous adverse outcomes in more than one LOB…"

3.1.4. Independent risks

3.22. Several risks covered in the standard formula are believed to be independent. Often, a correlation parameter of 0 is considered to be the best choice for the aggregation of independent risks. However, this is not always the case. The following example illustrates this point.

3.23. Example: Let *X* and *Y* be independent random variables, and assume that both follow a centralised and truncated lognormal distribution. The underlying non-truncated lognormal distribution has a mean of 1 and a standard deviation of 0.1. It is capped at 0.2; this corresponds approximately to the 98% quantile of the distribution. The risks *X* and *Y* could be underwriting risks mitigated by non-proportional reinsurance or hedged investment risks. Because of the capping at a quantile lower than 99.5%, VaR(*X*) = VaR(*Y*) = 0.2. By simulation, VaR(*X+Y*) can be determined as about 0.34. The value for VaR(*X+Y*) that is calculated by aggregating VaR(*X*) and VaR(*Y*) with the linear correlation coefficient of 0 is 0.28 and therefore lower than the correct result. In order to achieve an aggregation result of 0.34, a correlation parameter of 0.445 instead of 0 needs to be used.

3.24. It should be stressed that, whereas in the example above setting a correlation parameter of zero would result in an under-estimation of the aggregated risk, such a setting may also lead to an over-estimation of the required capital on the aggregated level. For example, if in the example a higher "cap" of e.g. 0.3 is selected, a negative correlation parameter would have to be set in order to reflect the aggregated risk.

---

[10] Cf. the above-mentioned article of Embrechts et al. for a definition of this concept and further analysis.
[11] See paragraph 6.20
(http://www.actuaries.org/LIBRARY/Papers/Global_Framework_Insurer_Solvency_Assessment-public.pdf).

3.25. The example illustrates that the choice of the correlation parameter for independent risks is not straightforward. If the underlying distributions are not normal, setting a correlation parameter of zero may lead to a mis-estimation of the aggregated risk.

3.26. Where the shape or type of the marginal risk distributions are known, it may sometimes be possible to determine a correlation parameter which more closely reflects the aggregated risks. However, in practice, this may often be difficult. Often the shape of the underlying distribution is not known or it differs from undertaking to undertaking and over time. For example, even if the distribution of an underlying risk driver is known, hedging and reinsurance may have modified the net risk in an undertaking-specific way.

3.27. Hence where a standard formula correlation parameter has to be specified between two risks which can be assumed to be independent but such uncertainties exist, it appears to be acceptable to choose a low correlation parameter, reflecting that model risk may lead to an over- or under-estimation of the combined risk.

3.1.5. Market risk

3.28. In QIS4, the following correlation matrix was used:

	Interest rate	equity	property	spread	currency	concen-tration
interest rate	1					
equity	0	1				
property	0.5	0.75	1			
spread	0.25	0.25	0.25	1		
currency	0.25	0.25	0.25	0.25	1	
concentration	0	0	0	0	0	1

3.29. Concerning the appropriateness of these coefficients, in the feedback received it was suggested that the correlation between equity risk and interest rate risk could be reviewed, and that a higher correlation would be more appropriate. Also, it was found that for a number of correlation pairs the average coefficient chosen for internal models differed from the correlation coefficients specified for QIS4.

3.30. In view of these results and considering the materiality of the market risk correlations, CEIOPS has carried out extensive both qualitative and quantitative analysis to revise the correlation parameters of the market risk model in line with the 1:200 VaR target level for the calculation of the SCR.

3.31. In its Consultation Paper, CEIOPS set out a qualitative assessment of the "lessons learned" from the financial crises with regards to this issue; and has proposed to increase the correlation coefficients for a number of risk pairs.

3.32. During the consultation, stakeholders have commented that such qualitative analysis in itself would be insufficient to derive an appropriate a revision of the factors. They took the view that it would not be sound from a statistical perspective if a calibration of correlations should be based exclusively on the observations derived from the current crises, and suggested that CEIOPS should undertake a more thorough statistical analyses based on historic data from a longer period of time.

3.33. CEIOPS acknowledges these concerns and has undertaken such further statistical analysis on basis of a methodology which is consistent with the general aims of setting correlation parameters as set out in section 3.1.3. This intended

- to determine the overall level of diversification implied by the correlation matrix proposed, and to assess its appropriateness; and

- to statistically assess the correlation between individual pairs of risks in the market risk module using historical data.

3.34. The following paragraphs set out the results of CEIOPS analysis on this issue. More detailed background information on the statistical quantitative analysis undertaken is provided in the annex.

General considerations and lessons learned from the financial crises:

3.35. The current financial and economic crisis provided further strong empirical evidence that the dependence structure of market risk changes in stressed situations.[12] Risk factors that have not revealed a significant correlation during ordinary market conditions showed a strong dependence in the crisis. It could also be observed that the risks had a reinforcing effect on each other.

3.36. For all risks that are covered by the market risk module a strong simultaneous change in market parameters was observed:

- Credit spreads widened in an unprecedented manner.

- The market price for equity fell stronger than during the crises in 1973 or at the beginning of the century. The MSCI world index dropped by 40% and the STOXX 600 by 46% in 2008.

- Interest rates fell sharply, for example for German 10 year Government bonds by 30% in the second half of 2008. The key

---

[12] We note that such a change in the dependence structure of market risks in stressed situations could also be observed during previous crises, for example during the dot.com crisis after the turn of the century or during the crisis in Southeast Asia in 1997.

interest rates of the U.S. Federal Reserve System and the Bank of England were set to historic lows.

- Property prices in some markets strongly decreased. In the United States the Case Shiller Index dropped by 19% in 2008. Similar declines could be observed in some European markets.[13]

- Exchange rates were also quite volatile. For instance, the British Pound lost 24% against the Euro in 2008. Also the currencies of Iceland and some other states outside of the Euro zone came under pressure.

3.37. This simultaneous adverse change across a range of market risk drivers left only limited scope for diversification, i.e. it was very difficult for market participants to offset losses with respect to one risk category with gains in other risk categories. Only where risks have a two-sided nature like interest rate risk or currency risk, market participants were able to offset risks if they were on the "right" side (for example short in Icelandic króna or short in interest rates).

3.38. CEIOPS considers that for the calibration of the correlation parameters in the market risk module of the SCR standard formula the empirical evidence provided by the current crisis on the existence of a significant degree of tail correlations between different market risk drivers should not be ignored. In line with its general observations on the calibration of correlation parameters as set out in section 3.1.3., CEIOPS has reflected this tail dependency in its statistical analysis for setting the correlation parameters in order to ensure that the aggregated capital requirements are in line with the 99.5% confidence level for the calculation of the SCR.

Overall diversification benefit implied by proposed correlation matrix

3.39. To test the overall appropriateness of the correlation matrix proposed in its draft advice, CEIOPS has carried out a statistical "top down" modelling analysis to assess whether the overall diversification benefit implied by the matrix is consistent with the 1:200 year confidence level targeted for the determination of the capital charge for market risk as a whole.

3.40. The diversification benefit implied by the matrix can be measured as

$$1 - \frac{SCR_{mkt}}{\sum_{r} Mkt_r}$$

where SCR_{mkt} denotes the capital charge for market risk, Mkt_r denote the capital charges for the individual market risks, and where

$$SCR_{mkt} = \sqrt{\sum_{rxc} CorrMkt_{r,c} \bullet Mkt_r \bullet Mkt_c}$$

---

[13] However real estate markets in other countries (e.g. Germany) were less affected.

is derived from the capital charges for the individual sub-risks by using the proposed correlation matrix $CorrMkt_{r,c}$.

3.41. This diversification benefit as implied by the aggregation matrix is consistent with the targeted confidence level of 99.5% for market risk if it coincides with the risk-theoretic diversification benefit which is given as

$$1 - \frac{VaR_{mkt}}{\sum\limits_{r} VaR_r}$$

where VaR_{mkt} denotes the Value-at-Risk 99.5% capital charge for market risk as a whole and VaR_r denote the Value-at-Risk capital charges for the individual sub-risks of market risk.

3.42. Assuming that the calculation of the capital charges Mkt_r of the individual sub-risks are commensurate with the 99.5% Value-at-Risk confidence level, it follows that the diversification benefit implied by the matrix is consistent with the 99.5% confidence level if the capital charge SCR_{mkt} derived from aggregating the individual charges with the correlation matrix coincides with the risk-theoretic 99.5% Value-at-Risk capital charge VaR_{mkt} for market risk as whole, i.e. if the aggregation error

$$\left| VaR_{mkt} - \sqrt{\sum\limits_{r \times c} CorrMkt_{r,c} \bullet Mkt_r \bullet Mkt_c} \right|$$

is zero.[14]

3.43. To carry out the analysis, a model of a 'typical' European insurer as described in QIS4 was created with a standalone capital for market risks of 100. This is made up of:

Interest rates	29.36
Equity	39.24
Property	8.39
Spread	11.00
Currency	5.22
concentration	6.80

3.44. Using 12 years[15] of historical data for year on year falls in indices relating to each of the market risks, a simulated empirical calculation of the Value-at-Risk capital charges for the individual market sub-risks as well as for market risk as a whole was undertaken. This empirical simulation exercise then allowed a comparison of the risk-theoretic diversification benefit with the diversification benefit implied by the proposed correlation matrix.[16]

---

[14] We note that this observation is consistent with CEIOPS' overall aim to determine the correlation parameters in the standard formula such that the aggregation error is minimised, cf. section 3.1.3, above.
[15] 12 years was chosen, as this was the longest time period for which data existed for all of the main risks considered.
[16] This was computed as shown in the formula, above, where the individual charges Mkt_r were estimated by the empirical Value-at-Risk capital charges for the individual sub-risks.

3.45. Considering this empirical analysis, the risk-theoretic diversification benefit for the aggregated market risk (in relation to its sub-risks) was determined as 17.3%, whereas according to the analysis the diversification benefit implied by the proposed correlation matrix was measured as 16%. This indicates that the correlation matrix proposed in CEIOPS' Consultation Paper provides overall capital figures which are broadly consistent with the targeted 99.5% Value-at-Risk confidence level. The analysis also included sensitivity testing of key assumptions, which indicated that the results of the analysis are relatively robust.

3.46. Not withstanding this overall indication that the correlation matrix for market risk on which CEIOPS consulted appears to be broadly adequate, CEIOPS has undertaken further analysis on specific correlation pairs, as explained below. The revised proposal for a correlation matrix as set out in this paper is expected to lead to higher diversification benefits than estimated above.

3.47. For further detail on the analysis please refer to appendix A.

Statistical analysis on correlation between specific sub-risks

3.48. For the setting of correlation parameters between specific pairs of sub-risks in the market risk module, CEIOPS has complemented its qualitative assessment set out in its draft advice by a quantitative statistical analysis. This was based on an analysis of historical data on the year-on-year percentage changes in the underlying risk drivers.

3.49. For example, to consider the correlation between interest rate risk and equity risk, the analysis was based on the MSCI world equity index from 1970, compared with UK 10 year spot.

3.50. As was noted above, in view of the assumed tail dependence of market risks in stressed situations the correlation analysis was based on "cutting out" adequate subsets of data pairs in order to obtain a measure of the tail correlation, as well as a measure of the 'weight' in the tail as opposed to that expected by a simulated Gaussian copula.

3.51. Typically this involved a cut along various percentiles in each of the two variables. For example, the red boxes in the diagram below represent the data in the 99th percentile for equity and interest, the 95th percentile for both, and the 90th percentile for both:
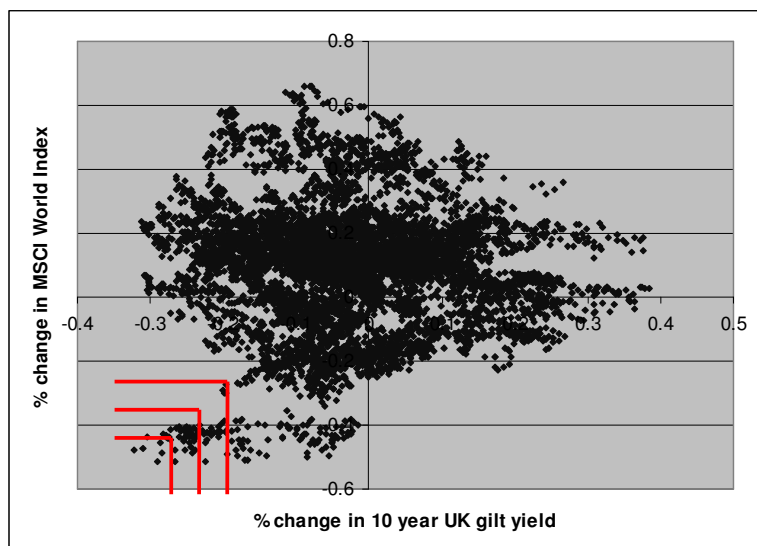
Overall dependence between market sub-risks in stressed situations

3.52. A strong fall of equity prices as reflected in the equity sub-module (-45%/-60%) does not leave the other market parameters unaffected. A drastic change in equity prices of this scale indicates an economic recession and a severe reduction of undertakings' expected profit. Such a situation is usually accompanied with an increase of risk-aversion and higher default probabilities. Therefore, credit spreads can be expected to increase sharply as well. For the same reason the demand for property, in particular commercial property, can be expected to decrease leading to vacancies and lower property prices. On the other hand, if credit spreads widen as greatly as in the spread risk sub-module, it signals an increased risk aversion and higher default probabilities. These circumstances would certainly affect directly or indirectly the expected profits and the market value of stock corporations in a relevant way, causing a fall in equity prices. Similar arguments apply to property risk. All three risks are intrinsically connected via the economic conditions, so that in extreme situations, they relate to each other in a similar way as in a causal relationship. These considerations indicate that a higher correlation factors between these risks might be appropriate.

3.53. Concerning the dependence between interest rate risk and other sub.-risks, we note that the monetary policy of the relevant central banks usually reacts to an economic downturn (and in particular to a fall in equity markets) by lowering the key interest rates. This can be observed for example in the 2001-2003 downturn where the ECB changed the key interest rate for the euro from 4.75% to 2% or the current crisis where rates fell from 4.25% to 1%. Similar reactions took place in the UK (6% to 3.5% and 5.75% to 0.5% resp.) and the US (6.5% to 1% and 5.25 to 0.25% / 0% resp.). These are direct reactions to the adverse movements of the market parameters which are addressed in the market risk module, such as equity prices, credit spreads, property prices and exchange rates. The central banks attempt to flood the market with cheap money in order to mitigate the worsening of these parameters. If key interest rates fall sharply in economic crisis situations, then so do the risk-free interest

rates. Therefore a high correlation of a fall in interest rates with an adverse change in the other market risks can be appropriate..

Correlation between interest rate risk and equity risk

3.54. CEIOPS has carried out additional statistical analysis on the correlation between interest rate risk and equity risk as described above.

3.55. The results of this analysis indicate that the proposed correlation of 50% in the draft advice does not appear unreasonable. There is clearly a positive correlation between equity and interest rates, so the QIS4 proposal of a 0% correlation does not appear to be adequate.

3.56. On the other hand, a distinction should be drawn between correlations between a fall in interest rates and a fall in equity prices on the one hand, and between a rise in interest rates and a fall in equity prices on the other hand. Whereas there is clear statistical evidence of a positive correlation (in the range of 40% to 50%) between the first, much less data is available to support an analysis of the correlation between a rise in interest rates and a fall in equity prices.

3.57. In light of these conclusions, CEIOPS proposes to introduce a two-sided correlation between interest rate risk and equity risk in the standard formula:

- In case the insurer is exposed to a fall in interest rate risk, a correlation parameter of 50% between interest rate risk and equity risk should be applied to aggregate the respective capital charges;

- In case the insurer is exposed to a rise in interest rate risk, a correlation parameter of 0% between interest rate risk and equity risk should apply.

- The correlation parameter then results from the decisive risk for the undertaking. Therefore the application of the two-sided correlation depends on whether a fall or rise in interest rates is the crucial factor.

3.58. A minority of CEIOPS Members proposes not to change the QIS4 correlation between interest rate and equities, set at 0 in QIS4, on the basis of the remaining open issues in the evidence needed, and the high impact of any change.

Correlation between interest rate risk and property risk

3.59. The results of this analysis indicate that the proposed correlation of 50% in the draft advice does not appear unreasonable. It could even be argued that the data at the 80th and 85th percentile indicates that the correlations between property and interest rates should be closer to 75% than to 50%.

3.60. On the other hand, as in the case for the correlation between interest rate risk and equity risk, a distinction should be drawn between correlations

between a fall in interest rates and a fall in property prices on the one hand, and between a rise in interest rates and a fall in property prices on the other hand. Whereas there is clear statistical evidence of a positive correlation between the first, this is less strong in the case of a correlation between rising interest rates and falling property prices, where in some instances even a negative correlation can be observed.

3.61. In light of these conclusions, CEIOPS proposes to introduce a two-sided correlation between interest rate risk and property risk in the standard formula:

- In case the insurer is exposed to a fall in interest rate risk, a correlation parameter of 50% between interest rate risk and property risk should be applied to aggregate the respective capital charges;

- In case the insurer is exposed to a rise in interest rate risk, a correlation parameter of 0% between interest rate risk and property risk should apply.

- The correlation parameter then results from the decisive risk for the undertaking. Therefore the application of the two-sided correlation depends on whether a fall or rise in interest rates is the crucial factor.

Correlation between interest rate risk and spread risk

3.62. The results of this analysis indicate that the proposed correlation of 50% in the draft advice does not appear unreasonable, especially in view of an increased dependence in the tail of the distributions.

3.63. As was the case for the correlation between interest rate risk and equity risk or property risk, the analysis indicates that there is stronger support for a positive correlation in case of falling interest rates than in the case of rising interest rates.

3.64. In light of these conclusions, CEIOPS proposes to introduce a two-sided correlation between interest rate risk and spread risk in the standard formula:

- In case the insurer is exposed to a fall in interest rate risk, a correlation parameter of 50% between interest rate risk and spread risk should be applied to aggregate the respective capital charges;

- In case the insurer is exposed to a rise in interest rate risk, a correlation parameter of 0% between interest rate risk and spread risk should apply.

- The correlation parameter then results from the decisive risk for the undertaking. Therefore the application of the two-sided correlation depends on whether a fall or rise in interest rates is the crucial factor.

Correlation between equity risk and spread risk

3.65. In the analysis it was observed that year on year changes to credit spreads tend to be relatively stable, except for a few events (two in the last 12 years), where they jump rapidly. It seems plausible that such a jump would be seen in a general 1:200 year event (such as 2008).

3.66. Hence in the analysis of empirical correlations between equity and spreads were assessed at higher percentiles, and on condition of extreme movements in credit spreads. The results of this analysis indicate that empirical correlation between equity risk and property risk rises rapidly in the tail.

3.67. Given this tendency for very high correlations during periods of market stress, we can conclude that the CEIOPS proposed correlation factor of 75% is reasonable.

Correlation between property risk and spread risk

3.68. In the analysis similar anomalies between spread risk and property risk were observed as between spread risk and equity risk. Correlations between spread and property approach 50% in the 95th percentile..

3.69. Given these results, CEIOPS proposes to apply a correlation factor of 50% (rather than as 75% as suggested in the draft advice) between property risk and spread risk.

Correlation between equity risk and property risk

3.70. The statistical analysis indicates that the correlation of 75% as proposed in the draft advice would seem justified.

Correlation between currency risk and other risk types:

3.71. If these drastic changes in key market parameters take place it is likely that not all markets are affected in the same way and that currency exchange rates between the markets become volatile. On the other hand, strong movements in the exchange rates of main currencies can cause or reinforce the movements of other market parameters. These connections can be observed in the 1973 dollar crisis, the 1997 Asian crisis or the current financial crisis. Therefore, high correlation factors between currency risks and the other market risks can be adequate. On the other hand, currency risk is a two-sided risk. Depending on the currency mismatch, a fall in a currency exchange rate can cause a loss or a profit in the balance sheet of an undertaking. Taking this nature of currency risk into account, a medium correlation factor seems to be justified.

Correlation between concentration risk and other risk types:

3.72. The correlation factors of concentration risk in relation to equity risk, spread risk and property risk depend on the definition of concentration risk. The concentration risk sub-module covers the additional loss (compared to a well-diversified portfolio) that the undertaking may incur if

concentrations in the equity, bond or property portfolio in respect to a single counterparty exist.[17] Therefore, because of the definition of the concentration risk sub-module, the correlation factors should properly describe the dependence between the risk of concentrations with respect to counterparty exposure, and the equity, spread and property risk. The correlation factors of concentration risk in relation to equity, spread and property risk should allow for diversification between property and equity/spread risk. For example, there is diversification between equity risk and property concentration risk or between property risk and the risk of concentration in names. Hence the correlations factors of concentration risk in relation to equity risk, spread risk and property risk should be 0.50.

3.73. The correlation factors of concentration risk in relation to the other risks, namely interest rate risk and currency risk, should be set in a consistent manner, reflecting the dependence of these risks and the triple consisting of equity risk, spread risk and property risk.

3.74. Based on the analysis above, CEIOPS proposes that the correlation factors for market risk should be chosen as follows[18]:

	interest rate	equity	property	spread	currency	concen-tration
interest rate	1					
equity	0.5/0	1				
property	0.5/0	0.75	1			
spread	0.5/0	0.75	0.5	1		
currency	0.5	0.5	0.5	0.5	1	
concentration	0.5	0.5	0.5	0.5	0.50	1

3.75. It should be noted that in many cases (and nearly all cases between the four largest risks of interest, equity, property, and spread), the CEIOPS analysis gives a proposal consistent with the recent paper published by the CRO forum.[19]

Impact of proposed changes

3.76. Compared to the QIS4 choice of the calibration factors, the proposed factors would lead to an increase of the market risk capital requirement of

---

[17] Cf. CEIOPS' Advice on SCR market risk module (CEIOPS-DOC-40/09). The calibration procedure defined in Annex A determines the additional loss caused by the concentration. There is no diversification between this loss and the loss of the well-diversified portfolio.
[18] The choice of the bi-directional parameter depends on the decisive risk for the undertaking. In the case where the insurer is exposed to a fall in interest rate risk, a correlation parameter of 50% should be applied between interest rate risk and equity, property and spread risk. Otherwise, a correlation parameter of 0% should be applied.
[19] Calibration recommendation for the correlations in the solvency II standard formula.

about 26%. This results in an increase of the Basic SCR of about 21% for life insurance and about 6% for non-life insurance. (See Annex A for more detailed results.)

3.1.6 Life underwriting risk module

3.77. In QIS4 the following correlation matrix was used:

	mortality	longevity	disability	lapse	expenses	revision	CAT
mortality	1						
longevity	-0.25	1					
disability	0.5	0	1				
lapse	0	0.25	0	1			
expenses	0.25	0.25	0.5	0.5	1		
revision	0	0.25	0	0	0.25	1	
CAT	0	0	0	0	0	0	1

3.78. There is no appropriate data base for the calibration of the life underwriting risk correlation factors. For the time being, the choice of these factors needs to be based on expert opinion.

Mortality risk and longevity risk

3.79. Between mortality risk and longevity risk, a high diversification can be assumed to exist. For one insured person, both risks can completely hedge each other. However, the same may not apply to sub-portfolios under mortality risk and sub-portfolios under longevity risk commonly held by insurance undertakings for the following reasons:

  • The insured persons of both sub-portfolios may differ significantly. In particular, the sub-portfolio under mortality risk may relate to a different age cohort than the sub-portfolio under longevity risk. For example, the insured with a mortality cover may be young while the insured with a longevity cover may be old. A change in the mortality table may affect both sub-portfolios in such a way that losses in one sub-portfolio are not offset by profits in the other.

  • Different tables may apply to the two sub-portfolios. For example, the tables may be based on different data bases and they may be updated independently. In this case, one table may be changed

while the other one may remain unchanged. Again, no offset between profit and loss would be observed in such a case.

3.80. However, we note that such restrictions to an off-setting between mortality risk and longevity risk may be limited in case of a more severe systematic shock to mortality experience (e.g. an earthquake, a medical advance) which would have an "across the board" impact on mortality that affects a wide cross-section of policyholders.

3.81. For these reasons, the correlation factor should not be -1. As in QIS4, a low negative value like -0.25 appears to be appropriate.

Expense risk

3.82. Some insurance events like lapse, disability and revision can lead to additional expenses for the undertaking. For example, in case of a mass lapse event the number of transactions increases drastically and the internal processes of the undertaking would need to be adjusted accordingly. Moreover, a revision of the economies for scale in relation to the future expensed would need to be made. In case of an increased probability of disability events or annuity revisions, the expenses for the assessment and management of these events will rise.

3.83. In order to allow for this causal connection, similar to QIS4, a medium correlation factor of 0.5 for lapse, disability and revision risk in relation to expense risk seems to be appropriate.

Correlations with CAT risk

3.84. Catastrophe risk stems from extreme or irregular events whose effects are not sufficiently captured in the other life underwriting risk sub-modules. Examples could be a pandemic event or a nuclear explosion.[20]

3.85. It seems likely that a crystallisation of such an extreme event will have an effect on mortality, disability, lapse and expense experience. Hence it seems appropriate to set a correlation coefficient of 25% between CAT risk and either one of these other four sub-risks.

Other correlation factors

3.86. For all other pairs of risks, there is likely to be a low dependence or independence. In the case where the two risks can be assumed independent, following the analysis carried out in section 3.1.4., a correlation factor of zero (as in QIS4) seems to be appropriate, since no general assumption on the shape and type of the distributions of the sub-risks is made. In relation to the other pairs where there is low correlation, a coefficient of 25% appears to be adequate.

---

[20] Cf. CEIOPS-DOC-42/09

3.87. The correlation factors for life underwriting risk should be chosen as follows:

	mortality	Longevity	disability	lapse	expenses	revision	CAT
mortality	1						
longevity	-0.25	1					
disability	0.25	0	1				
lapse	0	0.25	0	1			
expenses	0.25	0.25	0.5	0.5	1		
revision	0	0.25	0	0	0.5	1	
CAT	0.25	0	0.25	0.25	0.25	0	1

Impact of proposed changes

3.88. Based of the results of QIS4, the impact of the suggested changes to the correlation matrix can be assessed. On average, for life insurance undertakings an increase of the life underwriting risk capital requirement by 4% and an increase of the Basic SCR by 1% can be expected. (See Annex A for more detailed results.)

3.1.7 Non-life underwriting risk-module

3.89. In QIS4 the following correlation matrix was used:

	premium and reserve	CAT
premium and reserve	1	
CAT	0	1

3.90. The non-life underwriting risk-module consists of two sub-modules: the non-life premium and reserve risk sub-module and the non-life catastrophe sub-module. The scope of the catastrophe sub-module is defined to cover extreme or exceptional events. If the sub-module fully captures the loss caused by these events and they occur independently from other loss events, the premium and reserve risk and catastrophe risk are independent.

3.91. However, the clear distinction between both risks may not be feasible in practice. For example, the catastrophe sub-module may cover an extreme event regarding the main lines of business that it affects, but side-effects of the event on other lines of business may not be modelled explicitly for reasons of practicability. Instead they may be addressed in the premium and reserve risk module, causing dependence between both sub-modules. These concessions to practicability should be taken into account in the choice of the correlation factor.

3.92. Also, whilst we would agree that there should be a low or zero correlation between CAT and reserving risk, it would seem plausible to assume a higher correlation between CAT and premium risk. For example, when premiums are soft, weak terms and conditions are likely to increase CAT exposure; conversely, where CAT events crystallise, this may lead to further losses associated with premium risk.

3.93. Based on these reasons, the correlation factors for non-life underwriting risk should be chosen as follows:

	premium and reserve	CAT
premium and reserve	1	
CAT	0.25	1

Calibration of correlation parameters across lines of business

3.94. The premium and reserve risk module also uses correlations between different lines of businesses (LOB's) to estimate the combined standard deviation of premium and reserve risk. We note that these correlations, in contrast to all other correlations considered in this paper, are intended to directly aggregate standard deviations instead of capital requirements. Therefore, in this case the correlation parameters should be set as linear correlation coefficients.[21]

3.95. In order to estimate the combined standard deviation, as per 3.6, CEIOPS is required to provide a correlation matrix defined as follows:
$CorrLob^{rxc}$ = the cells of the correlation matrix $CorrLob$

3.96. In QIS4, the following correlation matrix was specified:[22]

---

[21] Cf. Section 3.1.3
[22] Cf. Annex B for a more detailed description. CEIOPS has also puvblished a calibration paper which includes a description on the derivation of these correlations, which is available on CEIOPS' website under http://www.ceiops.eu/media/files/consultations/QIS/QIS3/QIS3CalibrationPapers.pdf

CorrLob	1	2	3	4	5	6	7	8	9	10	11	12
1: M (3rd party)	1											
2: M (other)	0.5	1										
3: MAT	0.5	0.25	1									
4: Fire	0.25	0.25	0.25	1								
5: 3rd party liab	0.5	0.25	0.25	0.25	1							
6: credit	0.25	0.25	0.25	0.25	0.5	1						
7: legal exp.	0.5	0.5	0.25	0.25	0.5	0.5	1					
8: assistance	0.25	0.5	0.5	0.5	0.25	0.25	0.25	1				
9: misc.	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1			
10: reins. (prop)	0.25	0.25	0.25	0.5	0.25	0.25	0.25	0.5	0.25	1		
11: reins. (cas)	0.25	0.25	0.25	0.25	0.5	0.5	0.5	0.25	0.25	0.25	1	
12: reins. (MAT)	0.25	0.25	0.5	0.5	0.25	0.25	0.25	0.25	0.5	0.25	0.25	1

3.97. As set out in annex B, CEIOPS has considered a number of policy options with respect to the calibration of correlation parameters across lines of business. On basis of this analysis, it seems appropriate to keep the correlation coefficients at their current level until sufficient data across the European area is available to carry out a more detailed analysis of non-life correlations.

Impact of proposed changes

3.98. Based of the results of QIS4, the impact of the suggested changes to the correlation matrix can be assessed. On average, for non-life insurance undertakings an increase of the non-life underwriting risk capital requirement by 7% and an increase of the Basic SCR by 3% can be expected. (See Annex A for more detailed results.)

3.1.8 Health underwriting risk module

3.99. At current, there is no appropriate data base for the calibration of the health underwriting risk correlation factors. Therefore, for the time being, the choice of these factors needs to be based on expert opinion.

3.100.CEIOPS acknowledges that due to the specific risk characteristics of health insurance it may not always be appropriate to use the same correlation parameters in the $Health_{SLT}$ and $Health_{Non-SLT}$ sub-modules as they are applied in the Life and Non-Life modules, respectively. We suggest that further technical work should be carried out to assess the appropriateness of the proposed factors, based on relevant data across the European area.

Correlations between "Health SLT", "Health Non-SLT" and $Health_{CAT}$

3.101.At current, CEIOPS is reconsidering the structure of the health module. An integration of the CAT sub-module besides the $Health_{SLT}$ and $Healt_{NonSLT}$ modules is anticipated. In that case, the following matrix is proposed for aggregating the capital charges for $Health_{SLT}$, $Health_{Non-SLT}$ and health CAT risk to a combined Health charge:

CorrHealth	$Health_{SLT}$	$Health_{Non\,SLT}$	$Health_{CAT}$
$Health_{SLT}$	1		
$Health_{Non\,SLT}$	0.75	1	
$Health_{CAT}$	0.25	0.25	1

3.102.The correlation factor between $Health_{SLT}$ and $Health_{Non-SLT}$ has been lowered to 75% to acknowledge that there are some indications for different risks in Health SLT and Health Non-SLT.

Correlations between u/w risk components in "Health SLT"

3.103.No health-specific analysis for the calibration of the correlation factors was made. As there are no indications that the dependence between the sub-risks for health obligations differs substantially from the dependence for life obligations, the calibration is the same as the one used for the life underwriting risk module specified in CEIOPS' Draft Advice on correlations parameters (CEIOPS-CP-74).

$CorrHealth^{SLT}$	$Health_{mortality}^{SLT}$	$Health_{longevity}^{SLT}$	$Health_{ldisability/morbidity}^{SLT}$	$Health_{lapse}^{SLT}$	$Health_{expense}^{SLT}$	$Health_{revision}^{SLT}$	
$Health_{mortality}^{SLT}$	1						
$Health_{longevity}^{SLT}$	-0.25	1					
$Health_{ldisability/morbidity}^{SLT}$	0.25	0	1				
$Health_{lapse}^{SLT}$	0	0.25	0	1			
$Health_{expense}^{SLT}$	0.25	0.25	0.50	0.5	1		

$Health_{revision}^{SLT}$	0	0.25	0	0	0.50	1	

Correlation between disability risk for medical insurance and disability risk for income insurance

3.104. The calculation of the disability/morbidity sub-risks introduces a distinction between disability risk for medical insurance and disability risk for income insurance. The calculation set out in CP 50 implicitly assumes a correlation of 100% between these sub-risks. As there is no evidence of a material diversification between these two sub-risks, we propose to maintain this factor.

3.105.

$CorrHealth_{NonSLT}$	$Health_{Premium\&Reserve}^{NonSLT}$	$Health_{CAT}^{NonSLT}$
$Health_{Premium\&Reserve}^{NonSLT}$		
$Health_{CAT}^{NonSLT}$		

Correlations between Lob in "Health Non-SLT premium & reserve risk"

3.106. As set out in CP50, correlation coefficients have to be determined between the LOB's accident, sickness and workers' compensation. The following factors – in line with the assumptions used in QIS3 - are suggested for this purpose:

$CorrLob_{Non\ SLT}$	Accident	Sickness	WC
Accident	1		
Sickness	0.5	1	
Workers' Compensation	0.5	0.5	1

Correlation between premium and reserve risk in "Health Non-SLT premium & reserve risk"

3.107. As there are no indications that the risks of health lines of business differs substantially each other, CEIOPS suggest to keep the QIS4 factor of 50% for the correlation factor between premium and reserve risk.

3.1.9 Overall impact

3.108. Based on the results of QIS4, the combined impact of the suggested changes to all correlation matrices can be assessed. On average, an increase of the Basic SCR by 21% can be expected. For non-life insurance, the impact is 9% and for life insurance 21%. (See Annex A for more detailed results.)

3.1.10 Up-dating of correlation parameters

3.109. According to Article 111d the implementing measures for the SCR standard formula should also specify the procedures for updating the correlation parameters.

3.110. From a technical point of view, one of the main obstacles for the calibration of the correlation factors is the lack of empirical data describing the dependence between the risks that the SCR should capture.

3.111. For some risks, for example most market risks, the shortage of data is unavoidable as each year only one observation of the risk (change in interest rate, equity index etc.) can be made. For other risks like the underwriting risks, often an observation per year and undertaking can be made. For instance the annual change in the lapse rate used for the calculation of the best estimate can be observed for each undertaking. The observations may not be independent, but they still provide useful information. However, these data were not collected in the past, mainly because the underlying observations were of limited importance for the current supervisory regime.

3.112. The calibration would improve if the analysis of risk dependence was supported by an evaluation of empirical data. For this purpose, the necessary information could be collected from the supervised undertakings in the future. The relevant data would for example be

- For life mortality risk: the change in assumed mortality rates,

- For lapse risk: the change in assumed lapse rates and the average lapse rate,

- For life expense risk: the changes in assumed expense and inflation rates,

- For non-life underwriting risk: the combined ratios per line of business.

3.113. The collection of such data would not only support the calibration of the correlation factors but also of the modules and sub-modules of the standard formula.

3.114.Overall, CEIOPS considers that for the process of updating correlation parameters in the SCR standard formula an appropriate methodology should be developed which is consistent with the Solvency II 99.5% Value-at-Risk target criteria for the calculation of the SCR. Such methodology should include consideration of alternative dependence measures (such as tail correlation) for setting standard formula correlation parameters in cases where the use of linear correlations would not be adequate to capture the dependence structure between the risks.

3.2 CEIOPS' Advice

Choice of correlation parameters

3.115. The correlation parameters should be chosen in such a way to achieve the best approximation of the 99.5% VaR for the aggregated capital requirement.

3.116. In particular, the correlation parameters

- should deviate from linear correlation coefficients if the latter do not achieve this objective, and

- should allow for any tail dependence between risks.

Market risk module

3.117. CEIOPS has carried out additional statistical analysis on the correlation between interest rate risk and equity, property and spread risk. In light of this analysis, CEIOPS proposes to introduce a two-sided correlation between interest rate risk and equity, property and spread risk in the standard formula. The applicable correlation parameter then results from the decisive risk for the undertaking. The application of the two-sided correlation depends on whether a fall or rise in interest rates is the crucial factor.

3.118. The correlation factors for market risk should be chosen as follows:

	interest rate	equity	property	spread	currency	concentration
interest rate	1					
Equity	0.5/0	1				
Property	0.5/0	0.75	1			
Spread	0.5/0	0.75	0.5	1		
Currency	0.5	0.5	0.5	0.5	1	
concentration	0. 5	0. 5	0. 5	0. 5	0.5	1

The choice of the bi-directional parameter depends on the decisive risk for the undertaking. In the case where the insurer is exposed to a fall in interest rate risk, a correlation parameter of 50% should be applied between interest rate risk and equity, property and spread risk. Otherwise, a correlation parameter of 0% should be applied.

3.119.A minority of CEIOPS Members proposes not to change the QIS4 correlation between interest rate and equities, set at 0, on the basis of the remaining open issues in the evidence needed, and the high impact of any change.

Life underwriting risk module

3.120.The correlation factors for life underwriting risk should be chosen as follows:

	mortality	longevity	disability	lapse	expenses	revision	CAT
mortality	1						
longevity	-0.25	1					
disability	0.25	0	1				
lapse	0	0.25	0	1			
expenses	0.25	0.25	0.5	0.5	1		
revision	0	0.25	0	0	0.5	1	
CAT	0.25	0	0.25	0.25	0.25	0	1

Non-life underwriting risk module

3.121.The correlation factors for non-life underwriting risk should be chosen as follows:

	premium and reserve	CAT
premium and reserve	1	
CAT	0.25	1

Health underwriting risk module

3.122.At current, CEIOPS is reconsidering the structure of the health module. An integration of the CAT sub-module besides the Health$_{SLT}$ and Healt$_{NonSLT}$

modules is anticipated. In that case, the following matrix is proposed for aggregating the capital charges for Health$_{SLT}$, Health$_{Non-SLT}$ and health CAT risk to a combined Health charge:

CorrHealth	Health$_{SLT}$	Health$_{Non\,SLT}$	Health$_{CAT}$
Health$_{SLT}$	1		
Health$_{Non\,SLT}$	0.75	1	
Health$_{CAT}$	0.25	0.25	1

3.123. The correlation factors for the _u/w risk components in "Health SLT"_ should be chosen as follows:

CorrHealth^{SLT}	Health$_{mortality}^{SLT}$	Health$_{longevity}^{SLT}$	Health$_{ldisability\,y\,/\,morbidity}^{SLT}$	Health$_{lapse}^{SLT}$	Health$_{expense}^{SLT}$	Health$_{revision}^{SLT}$	
Health$_{mortality}^{SLT}$	1						
Health$_{longevity}^{SLT}$	-0.25	1					
Health$_{ldisability\,/\,morbidity}^{SLT}$	0.25	0	1				
Health$_{lapse}^{SLT}$	0	0.25	0	1			
Health$_{expense}^{SLT}$	0.25	0.25	0.50	0.5	1		
Health$_{revision}^{SLT}$	0	0.25	0	0	0.50	1	

3.124. The correlation factors _between Lob in "Health Non-SLT premium & reserve risk"_ should be chosen as follows:

CorrLob$_{Non\,SLT}$	Accident	Sickness	WC
Accident	1		
Sickness	0.5	1	
Workers' Compensation	0.5	0.5	1

Updating of correlation factors

3.125. It should be considered to collect appropriate data from the supervised undertakings in the future to support the revision of the correlation factors.

3.126. Overall, CEIOPS considers that for the process of updating correlation parameters in the SCR standard formula an appropriate methodology should be developed which is consistent with the Solvency II 99.5% Value-at-Risk target criteria for the calculation of the SCR. Such methodology should include consideration of alternative dependence measures (such as tail correlation) for setting standard formula correlation parameters in cases where the use of linear correlations would not be adequate to capture the dependence structure between the risks.

ANNEX A

Impact of proposed changes in correlation factors

A.1. This annex estimates the impact on the SCR of the proposed changes in correlation factor compared to QIS4. The analysis is done for each module separately and for the overall change.

A.2. The analysis is restricted to the impact on the capital requirements of the modules and on the Basic SCR. It is not possible to derive a reliable estimate for the change of the SCR from the available QIS4 data. This is owed to the non-linearity in the adjustments for technical provisions and deferred taxes. Depending on the situation, the relative increase of the SCR can be higher or lower than the relative increase of the Basic SCR.

Estimation methodology

A.3. If a correlation factor is changed then the relative impact on the aggregate capital requirement depends only on the relative sizes of the aggregated capital requirements, but not on the absolute value of the capital requirements.

A.4. For the impact analysis, the relative size of the capital requirements for each module and sub-module was chosen to be the average relative size as measured in QIS4. For each national market, the QIS4 database provides the relative importance of a risk and sub-risk. In order to arrive at a European average relative sizes, these data were weighted with the number of undertakings that provided the data in the national market. This approach results in relative importance of the risks as follows:

	all business segments	life insurance undertakings	non-life insurance undertakings	composite undertakings	reinsurance undertakings	captive undertakings
market	78,1%	81,7%	54,6%	85,1%	51,4%	37,4%
counterparty	4,2%	4,7%	6,4%	1,4%	3,0%	3,3%
life	21,0%	37,7%	1,1%	17,2%	12,8%	1,1%
health	5,7%	1,0%	17,2%	4,0%	3,4%	6,2%
non-life	29,0%	0,0%	62,0%	21,8%	40,7%	79,9%
interest rate	31,5%	39,6%	18,5%	35,2%	9,1%	8,7%
equity	42,1%	41,5%	30,7%	50,6%	14,5%	13,9%
property	9,0%	8,3%	7,2%	10,4%	0,6%	0,1%
spread	11,8%	13,6%	5,5%	12,0%	21,4%	2,3%
concentration	7,3%	3,9%	8,2%	5,6%	17,0%	18,9%
currency	5,6%	6,1%	3,5%	2,6%	7,2%	4,0%
mortality	2,3%	3,5%	0,0%	2,6%	1,9%	0,3%
longevity	7,4%	10,4%	0,4%	4,8%	7,5%	0,1%
disability	3,1%	4,8%	0,5%	1,6%	2,9%	0,0%
lapse	10,0%	22,1%	0,2%	8,2%	2,5%	0,0%
expense	4,0%	7,0%	0,2%	4,6%	0,9%	0,0%
revision	0,1%	0,1%	0,1%	0,1%	0,0%	0,0%
life CAT	3,9%	5,3%	0,1%	3,3%	5,3%	1,0%
non-life p&r	25,1%	0,0%	57,2%	20,3%	30,7%	37,0%
non-life CAT	9,6%	0,0%	17,4%	5,5%	22,5%	61,7%

A.5. For single undertakings the impact of the proposed changes can differ significantly from the estimated impact in this analysis, if the relative importance of the undertakings' risks differs from the average order of risks.

A.6. As CEIOPS proposes to introduce a two-sided correlation between interest rate risk and equity, property and spread risk, the applicable correlation parameter depends on whether a fall or rise in interest rates is the crucial factor. Due to data constraints a separation is not applicable in the QIS4 database. Thus the results are based on the assumption that for non-life insurance undertakings the upward stress is mainly relevant. Therefore a correlation of zero between interest rate risk and equity, property and spread risk is assumed for non-life insurance undertakings whereas for all other undertakings a correlation of 50% is applied in these cases.

A.7. The following figures do not take into account the changes to the scope of the health underwriting risk module compared to QIS4.

Results

A.8. The proposed change in the correlation matrix of the market risk module would result in changes in capital requirements as follows:

	Change in module capital requirement	Change in Basic SCR
Life insurance undertakings	27%	21%
Non-life insurance undertakings	14%	6%
Composite undertakings	25%	21%
Reinsurance undertakings	43%	24%
Captive undertakings	43%	10%
All undertakings[23]	**26%**	**20%**

A.9. The proposed change in the correlation matrix of the life underwriting risk module would result in changes in capital requirements as follows:

	Change in module capital requirement	Change in Basic SCR
Life insurance undertakings	4%	1,0%
Non-life insurance undertakings	5%	0,0%

---

[23] Under this approach, the impact may be slightly overestimated with decreasing granularity of the analysis. In particular, it can happen that the calculated impact for "all undertakings" is higher than for all of the aforementioned segments.

Composite undertakings	6%	0,4%
Reinsurance undertakings	8%	0,4%
Captive undertakings	7%	0,0%
All undertakings	**5%**	**0,5%**

A.10. The proposed change in the correlation matrix of the <u>non-life underwriting risk module</u> would result in changes in capital requirements as follows:

	Change in module capital requirement	Change in Basic SCR
Life insurance undertakings	0%	0%
Non-life insurance undertakings	7%	3%
Composite undertakings	6%	1%
Reinsurance undertakings	11%	4%
Captive undertakings	10%	7%
All undertakings	**8%**	**1%**

A.11. The proposed change in <u>all</u> correlation matrices would result in an overall change in capital requirements as follows:

	Change in Basic SCR
Life insurance undertakings	21%
Non-life insurance undertakings	9%
Composite undertakings	22%
Reinsurance undertakings	29%
Captive undertakings	18%
All undertakings	**21%**

Annex B Impact Assessment

1. Description of the policy issue

B.1. For undertakings using the standard formula to calculate their SCR, the extent of the diversification effects recognised in the non-life underwriting risk module as a result of the various correlation parameters (and/or interaction assumptions) across lines of business.

Brief description

B.2. The structure of the standard formula, by aggregating correlated risk modules, enables the recognition of the benefit of the diversification of these risks. Besides, where appropriate, diversification effects are taken into account in the design of each risk module (i.e. across sub-modules, where applicable) or sub-module (e.g. across lines of business and/or geographical areas).

B.3. The calculation of the group solvency capital requirement based on the consolidated balance sheet position of the group will lead to the recognition of further diversification effects amongst the different entities of a group.

B.4. The issue relates to the calibration of the various correlation parameters (and, where appropriate, design/calibration of the various interaction assumptions) underpinning the SCR standard formula, as well as their impact on the extent of diversification effects to be recognised at solo and group level. In this context, the following issue should be considered:

Calibration of correlation parameters across lines of business (non-life underwriting risk)

2. Description of the policy options for the calibration of correlation parameters across lines of business and assessment of the impact

Option 1

B.5. **Option 1:** use QIS4 correlation parameters across lines of business.

B.6. The QIS4 correlation parameters are specified as follows:

CorrLob	1	2	3	4	5	6	7	8	9	10	11	12
1: M (3rd party)	1											
2: M (other)	0.5	1										
3: MAT	0.5	0.25	1									

	1	2	3	4	5	6	7	8	9	10	11	12
4: Fire	0.25	0.25	0.25	1								
5: 3rd party liab	0.5	0.25	0.25	0.25	1							
6: credit	0.25	0.25	0.25	0.25	0.5	1						
7: legal exp.	0.5	0.5	0.25	0.25	0.5	0.5	1					
8: assistance	0.25	0.5	0.5	0.5	0.25	0.25	0.25	1				
9: misc.	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1			
10: reins. (prop)	0.25	0.25	0.25	0.5	0.25	0.25	0.25	0.5	0.25	1		
11: reins. (cas)	0.25	0.25	0.25	0.25	0.5	0.5	0.5	0.25	0.25	0.25	1	
12: reins. (MAT)	0.25	0.25	0.5	0.5	0.25	0.25	0.25	0.25	0.5	0.25	0.25	1

B.7. The QIS4 correlation parameters were based on a study performed by CEIOPS in preparation of QIS3 in 2007. Based on market data of German non-life insurers for the years 1988-2002 the correlations between the loss ratios of different lines of business were estimated. Where not a sufficient number of observations were available, the correlation parameter was based on expert opinion.[24]

B.8. CEIOPS acknowledges that the data basis is not ideal as it only covers the insurance market of one Member State. On the other hand, comparable data from other markets were not available. There are no indications that the correlations vary substantially with the market.

B.9. There seemed to be a broad consensus around the correlation coefficients that were used in the QIS4 specification for the non-life premium and reserve risk. In fact no comments were received on these correlations. It is assumed that the correlations as in QIS4 are neutral as to the orientation of the business by the undertakings and result in an adequate protection of the policyholder.

Option 2

B.10. **Option 2**: use lower than QIS4 correlation parameters across lines of business.

---

[24] See CEIOPS-FS-14/07 (QIS3 Calibration of the underwriting risk, market risk and MCR), pages 18-23.
(http://www.ceiops.eu//media/files/consultations/QIS/QIS3/QIS3CalibrationPapers.pdf)

B.11. Lower correlations will result in a lower capital requirement and may create inconsistencies with the assumptions on correlations taken for internal models. For less sophisticated firms however, lower correlations are likely to reduce the competitive disadvantage compared to undertakings using an internal model.

B.12. Depending on where the correlations are lowered there may be a shift towards that business that is the least capital intensive.

B.13. There may be an incidence on the premium level as lower capital requirements create some room for lower premiums. This is however an uncertain effect.

B.14. Lower correlation factors may lead to an underestimation of the 99.5 VaR calibration objective of the SCR and thereby reduce the protection of the policyholder.

B.15. CEIOPS has analysed the quantitative impact of a decrease of the correlation parameters. Based on QIS4 data the average distribution of premiums and technical provisions to the lines of business in the European market was determined. For an undertaking with this average business profile the sensitivity of the SCR for non-life premium and reserve risk was analysed.

B.16. For instance, if all correlation factors (apart from the diagonal values) were lowered by an absolute amount of 0.25, then the capital requirement for non-life premium and reserve risk would be **25% lower** which will directly impact the insurance undertaking (lower capital requirements) and indirectly the policyholders (decreased policyholder protection but lower prices).The corresponding correlation matrix is specified as follows:

CorrLob	1	2	3	4	5	6	7	8	9	10	11	12
1: M (3rd party)	1											
2: M (other)	0.25	1										
3: MAT	0.25	0	1									
4: Fire	0	0	0	1								
5: 3rd party liab	0.25	0	0	0	1							
6: credit	0	0	0	0	0.25	1						
7: legal exp.	0.25	0.25	0	0	0.25	0.25	1					
8: assistance	0	0.25	0.25	0.25	0	0	0	1				

9: misc.	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	1			
10: reins. (prop)	0	0	0	0.25	0	0	0	0.25	0	1		
11: reins. (cas)	0	0	0	0	0.25	0.25	0.25	0	0	0	1	
12: reins. (MAT)	0	0	0.25	0.25	0	0	0	0	0.25	0	0	1

<u>Option 3</u>

B.17. **Option 3**: use higher than QIS4 correlation parameters across lines of business.

B.18. The capital charge will be higher than under the previous options and a limitation of the production in those lines of business that generate the higher requirements is possible.

B.19. For sophisticated firms, higher capital charges may be an incentive to develop internal models and eventually lead to better control and management of the risks.

B.20. For less sophisticated firms however, the higher correlations may increase the competitive disadvantage of these undertakings compared to undertakings using an internal model.

B.21. Therefore, in setting the correlations to be used in the standard formula, a trade-off needs to be found between the increased risk sensitiveness and the ensuing capital charges.

B.22. Premiums may go up under this option but at the same time higher capital requirements also assure an increased level of policyholder protection.

B.23. The higher correlation parameters and the capital requirements following from this may limit accessibility of the products that increase in price.

B.24. The analysis explained in paragraph B.15 included also increases of the correlation parameters. For instance, if all correlation factors (apart from the diagonal values) were increased by an absolute amount of 0.25, then the capital requirement for non-life premium and reserve risk would be **21% higher,** which will directly impact the insurance undertaking (increased capital requirements) and indirectly the policyholders (increased policyholder protection but higher prices). The corresponding correlation matrix is specified as follows:

CorrLob	1	2	3	4	5	6	7	8	9	10	11	12
1: M (3rd party)	1											
2: M (other)	0.75	1										
3: MAT	0.75	0.5	1									
4: Fire	0.5	0.5	0.5	1								
5: 3rd party liab	0.75	0.5	0.5	0.5	1							
6: credit	0.5	0.5	0.5	0.5	0.75	1						
7: legal exp.	0.75	0.75	0.5	0.5	0.75	0.75	1					
8: assistance	0.5	0.75	0.75	0.75	0.5	0.5	0.5	1				
9: misc.	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	1			
10: reins. (prop)	0.5	0.5	0.5	0.75	0.5	0.5	0.5	0.75	0.5	1		
11: reins. (cas)	0.5	0.5	0.5	0.5	0.75	0.75	0.75	0.5	0.5	0.5	1	
12: reins. (MAT)	0.5	0.5	0.75	0.75	0.5	0.5	0.5	0.5	0.75	0.5	0.5	1

3. Operational objectives

B.25. The determination of the calibration between lines of business in non-life insurance falls under the scope of the following operational objectives:

- Introduce risk-sensitive and harmonized solvency standards

- Introduce proportionate requirements for small undertakings

- Promote compatibility of the prudential regime for EU insurers with the work of the IAIS and IAA

- Ensure efficient supervision of insurance groups and financial conglomerates

***Impact on industry, policyholders and beneficiaries and supervisory
    authorities***

<u>Costs and benefits</u>

- Industry

  The industry would benefit from lower correlation parameters, hence from
  increased diversification benefits (i.e. lower overall capital requirements).
  Lowering the level of correlations compared to QIS4 would result in a
  higher diversification benefit to be gained by undertakings. The ultimate
  level of correlations and its impact on the industry on average is difficult to
  assess, and revisions are possible in the future based on further evidence.
  Some lessons to be learned from the crisis should be taken into account to
  set the correlation factors commensurate with the risks run by an
  undertaking.

- Supervisory authorities

  Supervisors will benefit from a standard correlation matrix which will allow
  them to assess the undertakings in a harmonised manner. The ultimate
  level of the correlations may have to be reviewed after some years of
  implementation of Solvency II by an institution such as CEIOPS.

- Policyholders and beneficiaries

  Policyholders and beneficiaries would benefit indirectly from the reduction
  in capital requirements provided by a lower correlation. A higher
  correlation, which would result in higher capital charges may lead to an
  increase in the price of specific insurance products.

4. Comparison between the different options based on the efficiency and effectiveness in reaching the relevant operational options

B.26. The comparison and ranking of the policy options is based on the
      effectiveness and efficiency of each option in reaching the relevant
      objectives. Effectiveness is defined as the extent to which options achieve
      the objectives of the proposal. Efficiency is defined as the extent to which
      the objectives can be achieved at the lowest cost (cost-effectiveness).

B.27. With regard to risk-sensitivity and the harmonisation of the solvency
      standards, option 2 does not seem to be appropriate, as this would only
      lead to lowering the capital requirements compared to QIS4 even if it
      achieves the same level of harmonisation. Such option would only meet
      the option of proportionate requirements for small undertakings.

B.28. With regard to the introduction of proportionate requirements for small
      undertakings, option 2 seems most appropriate, as this would result on
      average in lower capital requirements.

B.29. In order to promote the compatibility of the prudential regime for EU insurers with the work of the IAIS and IAA, no clear view seems to be available yet. However, in line with the general developments to promote better risk management, there is some value in higher parameters enhancing better risk management although the risk of having higher premiums clearly constitutes a drawback.

B.30. The appropriate choice of correlation parameters between LoB will not only benefit solo undertakings, but also groups and financial conglomerates that carry out different LoB. The impact of the diversification effect due to the lower correlations in the basic correlation matrix may be greater in the case of a group due to other sources of diversification. However, this also creates complexities in the understanding of the economic reality of the group. Eventually, the level of correlation does not seem to have a direct impact on the efficiency of the group supervision.

B.31. Leaving the correlations at their current level is the third option and is an option around which a broad consensus exists. For the calibration exercise following QIS4, it was decided to keep the correlation parameters at their QIS3 level translating the broad support there is around these parameters and the lack of more evidence for changing the correlations.

B.32. In view of the crisis experience, the correlations in QIS4 may have been somewhat low. Furthermore, a trade-off needs to be found between the risk-sensitivity and the overall capital requirements. Thus, CEIOPS considers that the option to raise some of the correlation parameters fulfils the objectives in an efficient and effective manner.

Annex C Template for analysis of market risk correlations

C.1   In article 104 the level one text specifies that the standard formula approach to the SCR must be based on a correlation matrix with correlations being set such that the overall capital requirement is equivalent to a 99.5% one-year VaR stress.

C.2   This specification implies that a correlation matrix be chosen which has higher correlations than those which would be observed in normal market conditions. Intuitively, this can be understood as reflecting the fact that in stressed conditions, market risks generally take on a higher dependence (for example in the recent dislocation, equities and properties fell, spreads widened, and interest rates dropped: all to a large extent, and all at the same time).

C.3   To assess whether a correlation matrix provides a capital in line with a stress at the 99.5% VaR, we need to consider the matrix as a whole, and consider whether the diversification benefit it provides is consistent with that we would expect in a 99.5% VaR event.

C.4   In order to do this, we have created a model which calculates a market risk capital requirement based on actual historical market risk data. We can then compare this requirement against that calculated with reference to a correlation matrix.

1. Description of model

C.5   The model focuses on the impacts of the correlations, rather than the market risks themselves. As such it aims to check that the correlation matrix provides a figure consistent with a 99.5% VaR shock. It makes no assumptions regarding the distribution of risks, taking empirical historical values.

C.6   The steps to produce the model are as follows:

1.   Obtain a set of indices for the risks to which the company is exposed.
2.   Calculate the year on year percentage change for each of these indices.
3.   Multiply the value derived in 2 by a factor designed to reflect the normalised capital required on a standalone basis in respect of that risk.
So, for example, the observed 99.5[th] percentile year on year change for property is -25%. For the typical QIS4 firm we expect 8.4% of total capital to be in respect of property risk, so we multiply each year on year change in the property index by a factor of 100 * 8.4%/25%.   100   is   the   normalising   value. Performing this will ensure that the undiversified sum of the 99.5% VaR capital levels for all risks is 100.

4.   For each observation, sum the capital required to get a total capital requirement for that observation.

5.   Order the observations by total capital requirement.

C.7   We can observe the 99.5th worst capital result, which would correspond to a modelled 99.5% VaR event. This figure can give us an estimate of the diversification benefit deriving from the model.
We can then compare against an approach using a correlation matrix combined with the 99.5% VaR standalone capital requirements as defined for our typical firm. This figure shows us the diversification benefit implied by the matrix.

C.8   Comparing the two diversification benefit figures shows us whether the benefit implied by the matrix is too strong, or not strong enough.

1.1 Limitations

C.9   There are a number of limitations to this model which need to be considered.   Where possible we have examined the limitations of the model using sensitivities as described below.

1. Choice of Indices: The indices used may not be appropriate for each firm. The difficulty in calibrating data to concentration risk and FX risk means that analysis involving these two risks needs to be treated with caution, although as these are the least material of the market risks for a typical European firm, the importance is perhaps less high.
2. Data period: Our analysis only looks at a 12 year data period. This gives extra weight to the 2008 market crisis which may be unwarranted. Although we note that the level of increased correlations in 2008 could be interpreted as a reasonable 99.5%-level assessment of heightened correlations in times of extreme risk.
3. Overlapping data period: We have considered daily overlapping data periods. Preliminary analysis indicates that the auto correlation bias this introduces does not have a radical effect, and we consider the extra data gained from considering overlapping periods outweighs the bias.
4. Linear losses: The model assumes that a firm has linear losses, i.e. if a 10% fall in the equity index costs $10m, a 20% fall would cost $20m. This may not be accurate for many firms.
5. Structure of the firm: The model assumes a firm with capital requirements identical to those of a 'typical' QIS4 firm.   It thus blurs national, and sectoral distinctions, and only gives a high level view.

1.2 Results of the analysis

C.10   The analysis hypothesises a 'typical' European firm as described in QIS4 with a standalone capital for market risks of 100. This is made up of:

Interest rates	29.36
Equity	39.24
Property	8.39

Spread	11.00
Currency	5.22
Concentration	6.80

C.11 Under the empirical model, the 99.5th percentile capital requirement is 82.5, and under the Level 2 proposed matrix, the 99.5th percentile capital requirement is 83.7. The difference is low, with the level 2 matrix being slightly too prudent by approximately 1.2%.

C.12 <u>This indicates that the correlation matrix proposed by CEIOPS provides overall capital figures broadly consistent with a 99.5% VaR stress.</u>

1.3 Sensitivities to the analysis

C.13 The analysis may have the criticisms:
- The analysis is based on only 12 years of data.
- The analysis is based on a typical QIS4 firm, and a firm's exposure to different risks may differ materially from this.
- The risk factors used in the analysis do not represent an accurate proxy for a firm's own risks.

We have run some sensitivities on the model to assess the validity of these criticisms:

1.3.1 Percentiles Sensitivity

C.14 It could be charged that a 99.5% VaR event over the reference period of the last 12 years would not equate to a 'standard' 99.5% VaR event, as the last twelve years has seen an unusually high shock to market risk.

C.15 We can perform the same calculation as above with a number of percentages with the following results:

Percentile	Model	Matrix	Difference	% Difference
99.9	86.37	89.48	3.11	3.5%
99.5	83.74	82.53	-1.21	-1.5%
99	79.60	79.73	0.13	0.2%
98	76.13	75.23	-0.90	-1.2%
97	70.82	71.25	0.43	0.6%
96	65.22	68.23	3.01	4.4%
95	55.61	63.65	8.04	12.6%
90	35.35	49.98	14.63	29.3%
80	23.34	28.74	5.40	18.8%

C.16 As can be seen, at the 97th percentile and above, the model produces results which are very similar to the proposed correlation matrix. The correlation matrix gives appropriate results for any stress greater than a 1:30 event over the last 12 years. This can give us confidence that the model would be robust to longer periods of data.

C.17   The event which drives the model in the tail is the 2008 market dislocation, as described above. The correlation matrix proposed gives a similar diversification benefit as firms would have been able to take account of in 2008.

1.3.2 Sensitivity to different risk factors

C.18   The analysis is performed using the following proxies for risk factors:

Equity:	MSCI World Index
Interest:	UK 10 year swap rates
FX:	GBP / USD currency rates
Property:	A large portfolio of UK investment grade property (assessed monthly)
Spread:	The spread to gilts on UK AA rated corporate bonds
Concentration:	A simulated set of variables with a relatively high correlation with Equities.

C.19   We note that the proxies used may not accurately reflect the market risk holdings of various European insurance firms, so have provided the following analysis to show the sensitivity to different proxies.

- Using MSCI Europe index instead of MSCI world index
- Using DEM/EUR 10 year swap rates instead of UK rates
- Using spreads to gilts on European firms instead of UK firms

Sensitivity	Model	Matrix	Difference	%
Equity DEM	84.3	82.5	-1.8	-2%
Interest European	80.6	82.5	1.9	2%
Spreads	82.4	82.5	0.1	0%

C.20   As can be seen, whilst using different risk proxies has an effect on the overall result, the effect is not huge and the sign appears to be unbiased.

1.3.3 Sensitivity to different weightings

C.21   The analysis considers a 'typical' European insurance firm as calculated in QIS4, and so the relative weightings for the risk factors are based on this analysis.

C.22   We note that under CEIOPS' proposed new market risk stresses, the relative importance of the market risk factors may change, with some risks, such as equity and credit spreads adopting more relative importance.

C.23   We do not attempt to pre-empt the relative importance of these changes, but attach a sensitivity to increasing each relative weight by 50%. For example the equity stress assumes that the proportion of market risk capital due to equity increases from c40% to c60%.

Sensitivity	Model	Matrix	Difference	%
Equity	83.7	85.2	1.50	1.8%
Spread	79.8	83.6	3.80	4.5%
Property	82.8	83.6	0.80	1.0%
Interest	82.7	83.5	0.80	1.0%
FX	82.8	83.2	0.40	0.5%
Concentration	82.0	84.0	2.00	2.4%

We note a small change, especially for firms who have a larger exposure to equity or concentration than under QIS4. We note that where relative weights decrease, the change would be in the opposite direction.

1.4 QIS4 results on model

C.24 Under QIS4 correlation assumptions, the capital requirement would be 61.9. This compares with a model value of 82.5, and a matrix value of 83.7.

Undiversified	100
Model	82.5
Matrix	83.7
QIS4	61.9

On this analysis the QIS4 correlations are clearly too weak.

1.5 Conclusion

C.25 As can be understood by the tables showing the three sensitivities above, the analysis is relatively robust.
The correlations as proposed appear to produce a capital requirement for market risk which is approximately appropriate for a 99.5% VaR stress under a range of different plausible scenarios.

2 Correlation pairs

C.26   Having concluded that the correlation matrix is of an appropriate strength, it is now important to consider some of the individual correlation factors between key pairs of risks, to ensure that the pairs are not too high in some areas, and too low in others.

C.27   We focus particularly on the interest rate v equity and equity v spread pairs. This is because these pairs are amongst those with the generally highest impact to European firms. It should be noted that for both of these pairs, the CEIOPS final advice is consistent with the recommendation published by the CRO forum in their recent calibration document[25].

2.1 Equity / Interest

C.28   For this analysis, we consider MSCI world equity index from 1970, and FTSE index from 1986, compared with the UK 10 year spot rate: the significantly longer time period (using all available reliable data) should be noted.

2.1.1 'Weight analysis'

C.29   We simulate a Gaussian copula with empirical marginal distributions as described by the indices (using FTSE), and a correlation coefficient of 0.5 (in blue). On to this we overlay the empirical distribution of year on year changes (in red).
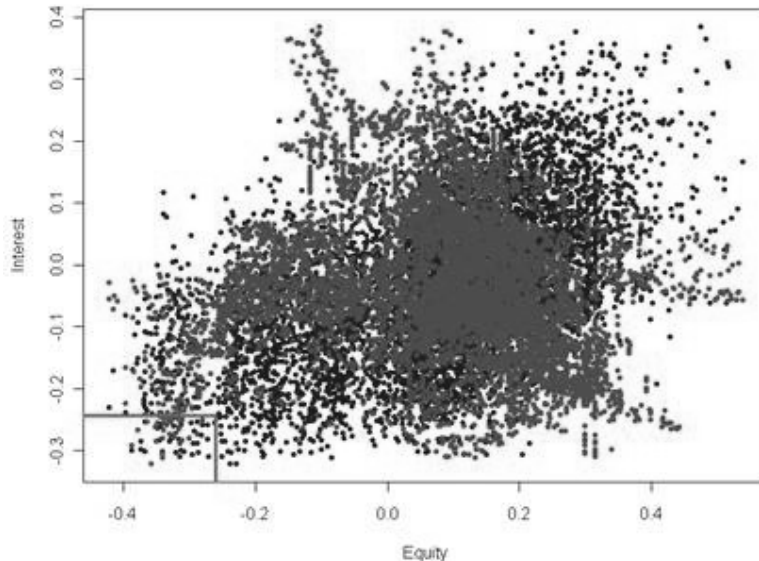
C.30   The figure shows us that the shape of

dependency is very different to that implied by a Gaussian copula. We can examine the tail at varying percentiles to examine whether the 'weight' of data points in the tail, is similar to that predicted by the Gaussian copula.

---

[25] CRO Forum: Calibration recommendation for the correlations in the Solvency II standard formula. 2009

C.31 Taking the 38 worst data points, (where 38 is the total number of data points/200), and applying different correlation coefficients we see the following results:

Correlation coefficient of copula	Observed data points	Expected data points
0%	38	2
50%	38	38
90%	38	123

C.32 The values predicted by a simulated Gaussian copula with correlation of 0.5 are similar (in fact the same) to those we have OBSERVED, indicating that a correlation of 0.5 seems reasonable. Simulated copulas with radically different correlation coefficients predict radically different numbers of data points in the tail.

2.1.2 Strength analysis

C.33 We have performed a strength analysis for a company exposed just to equity and interest rate risks, in the same way that we performed our overall strength analysis for all risks above.

C.34 Looking at equity and 10 year yield indices for as much data as is available, and for three separate markets, we see the following results:

| Data set	Data period		Equity weight	Interest weight	Model result	Matrix (50%)	Implied correlation
S&P 500 v US 10 yr Treasury	1983-2009		50	50	92	86.6	69%
S&P 500 v US 10 yr Treasury	1983-2009		70	30	94.5	88.9	74%
S&P 500 v US 10 yr Treasury	1983-2009		30	70	90.1	88.9	55%
Nickei 225 v JPY 10 yr	1982-2009		50	50	81.4	86.6	30%
Nickei 225 v JPY 10 yr	1982-2009		70	30	78.2	88.9	7%
Nickei 225 v JPY 10 yr	1982-2009		30	70	88.3	88.9	47%
FTSE AS v 10 yr UK BM Bond	1986-2009		50	50	92.8	86.6	69%
FTSE AS v 10 yr UK BM Bond	1986-2009		70	30	94	88.9	72%
FTSE AS v 10 yr UK BM Bond	1986-2009		30	70	93.2	88.9	69%

C.35 Note that we have theorised a company exposed to the two risks in three proportions: (1) 70% Equity v 30% Interest, (2) 50%/50% and (3) 30%/70%.

C.36 The results indicate a wide variety of implied correct correlations, depending on make up of company as well as the market examined. Many of the implied correlations are significantly greater than 0.5, and some much lower (note particularly the unique features of the Japanese market over the time period).

C.37 Given the range of results and the dependence on the assumptions used, CEIOPS considers this analysis does not give strong evidence to move away from a correlation of 50%, however it could be argued on the basis of these results that the correlation could be somewhat higher.

2.1.3 Data Cutting analysis

C.38 We calculated the year on year percentage change in both factors, and used these figures to calculate correlations.
A scatter chart showing the shape of the correlation can be seen:
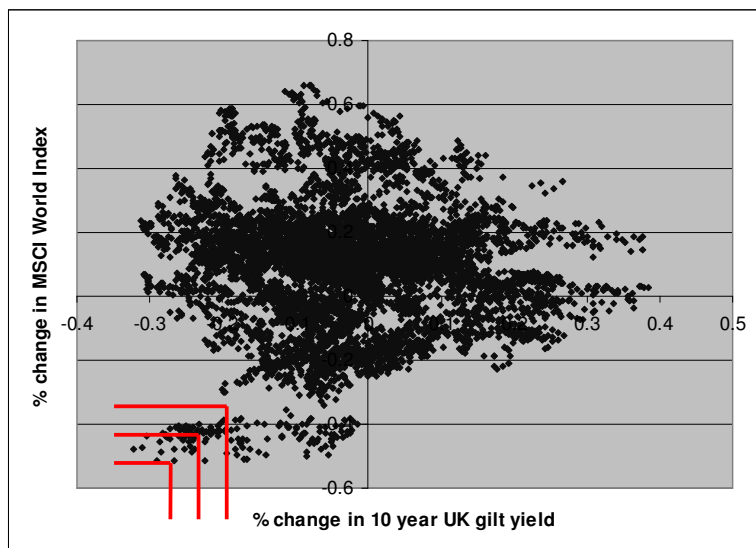
C.39 We can cut the data in various ways to get a measure of the tail correlation.
The red boxes represent the data in the 99th percentile for equity and interest, the 95th percentile for both, and the 90th percentile for both. The bottom left hand corner of the graph represents a fall in both equity and interest rates. The bottom right hand corner represents a fall in equity and a rise in interest rates.

Results

C.40 The percentiles of the equity and interest rate movements are:

Percentiles	Interest	Equity
99	-28%	-43%
95	-22%	-21%
90	-18%	-16%
80	-13%	-5%

C.41 Cutting the data to include only these percentiles provides the following results, and attendant correlations

Percentiles	Interest	Equity	Correlation
95	-22%	-21%	16%

90	-18%	-16%	37%
80	-13%	-5%	53%

There are only 6 data points in the 99th percentile for both equity and interest, and as such the correlation measure is unreliable.

Conclusions

C.42 As we can see, there is evidence to back up the assumption of a 50% correlation between equity and interest rates (especially if the '80%' percentile is chosen).

C.43 There are a few problems with relying on this data cutting analysis though:
- It is difficult to understand what percentile should be taken as an accurate tail correlation.
- Only data points from a relatively small period of time are driving the correlation calculations.

1. Choice of percentile for tail correlation analysis

C.44 As can be seen from the results, the choice of percentile is important in determining the correct correlation coefficient.
It is key to strike a balance between being adequately in the tail, and having enough data points for a reliable analysis. As described above the overall correlation matrix should produce a level of stress equivalent to a 99.5% VaR event, so each individual pair can be equivalent to significantly less than a 99.5th percentile stress, but still should be firmly in the tail.
The analysis must be subject to sensitivities for different percentiles, and should be taken as providing an indication of the correct correlation.

2. Data points from only one risk event

C.45 The following chart shows a plot of year on year FTSE and UK interest rate changes, coloured according to time period. As can be seen different time periods show different patterns of correlation and are generally grouped in different areas of the chart.
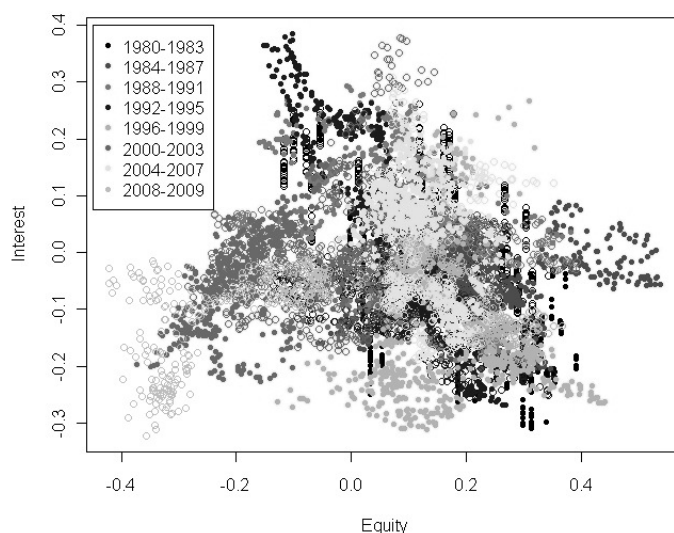
C.46 Ideally our analysis would be able to capture the effect of more than one period, and not just rely on the 2008 market crisis.

C.47 The below graph shows all data points of MSCI equity plotted against interest rates. Those with a red centre are from the period October 2008 to April 2009.


% change in 10 year UK gilt yield
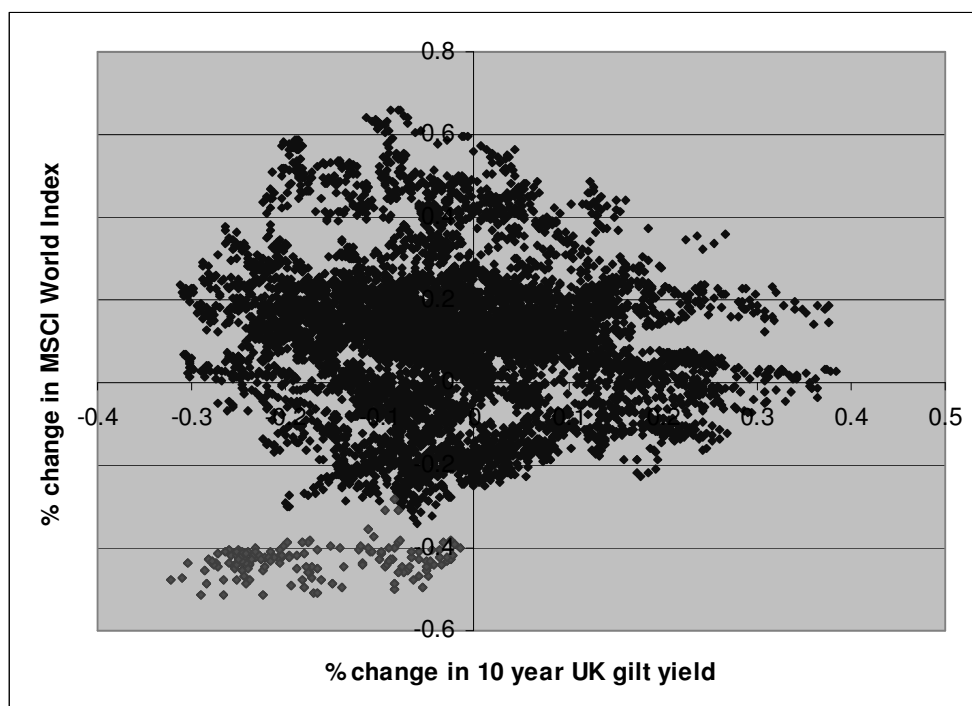
C.48 The data points from this six month period are by far the most extreme, and therefore dictate nearly all of the analysis performed on correlations with this method.

C.49 Removing these data points and performing the same analysis results in a tail correlation factor of 58% at the 90th percentile, and 63% at the 80th percentile. This could indicate that the 50% proposed by CEIOPS is, if anything, prudent.

2.1.4 Equity/Interest Conclusion

C.50 The proposed stress of 50% does not appear unreasonable, we have used three separate methods to analyse the correlation, and all provide results which are not inconsistent with 50%, some seem to indicate a slightly higher value is appropriate, and others that a slightly lower value is appropriate.
We note a further method, the so-called 'rolling correlation' method as described in the recent CRO Forum paper amongst others. For the equity/interest pair, this analysis places 50% firmly within the plausible range of correlations.

2.2 Equity/Spread

C.51 In order to analyse this pair, we have considered the return on an MSCI world index as compared to the spread to gilts on UK AA rated corporate bonds. This analysis is performed on just 12 years, as data on UK spreads (as for spreads in most other markets) does not exist for longer periods than this. All things being equal, the tail results we see over a short period should be less extreme than those we would see over a longer period.

C.52 The following chart displays the year on year percentage change for equities and spreads over the last 12 years (with higher spreads being seen as negative)
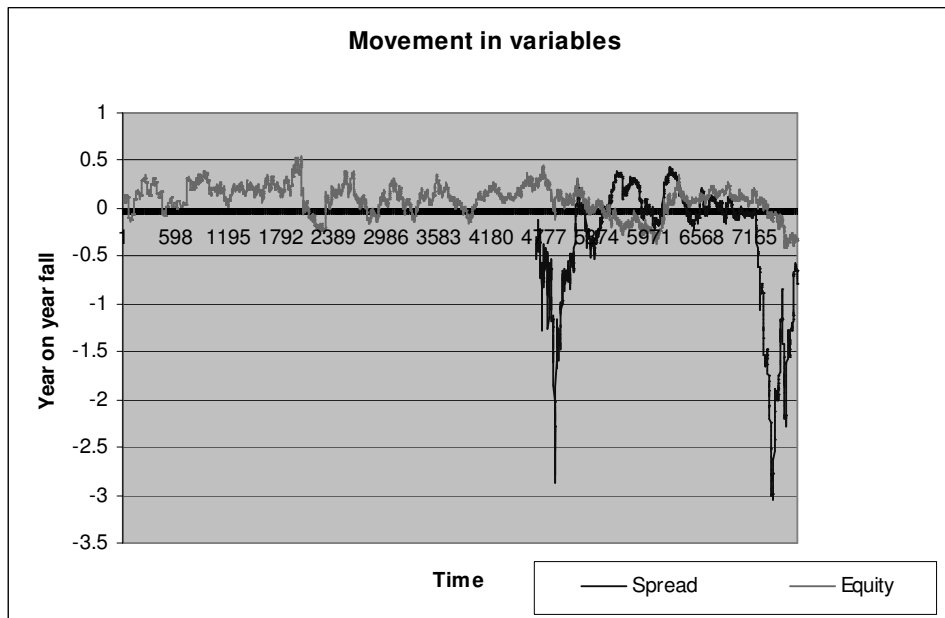
C.53 As can be seen there have been two large credit spread events in the last 12 years, the recent credit crisis, and the LTCM crisis, the second of these crisis corresponded to a large fall in equities, whilst the first corresponded to a somewhat smaller (and lagged) fall.

C.54 We can calculate the empirical correlations at different tail percentiles in the method described above:

Percentile	Correlation
75	-51%
80	-46%
85	-28%
90	23%

C.55 *Prima facie* this would indicate that the correlation is relatively low, and maybe even negative between equity and spread. However we can look at the quantiles these percentiles correspond to for a fuller picture:

	Equity	Spread
99.5	-34.6%	-285.0%
99	-33.0%	-270.1%
95	-21.9%	-190.1%
90	-13.9%	-137.0%
80	-4.3%	-73.1%

C.56   As we can see both in the above graph and the table, year on year changes to credit spreads tend to be relatively stable, except for a few events (two in the last 12 years), where they jump rapidly.

C.57   It is entirely plausible that such a jump would be seen in a general 99.5% VaR year event (such as 2008), and so we should examine the correlations between equity and spreads at more extreme percentiles, and particularly, we should condition on extreme movements in credit spreads, and calculate empirical correlations.

C.58   The following tables perform this analysis:

Percentile	Correlation
89	-4%
90	23%
91	41%
92	57%
95	72%

Periods of extreme credit stress movements

	Data points	Correlation
02/11/2007 to 27/02/2009	346	-21%
25/08/1998 to 29/01/1999	114	32%

Periods of very extreme credit stress movements

12/02/2008 to 08/05/2008	81	54%
30/09/1998 to 28/10/1998	21	75%

C.59   The first table indicates that empirical correlation rises rapidly in the tail. The second table, which conditions on extreme (2x year on year change) and very extreme (3x year on year change), demonstrates for what kind of events we can see high correlations.

C.60   In the last 12 years we have seen two periods of 'very extreme' changes to year on year credit spreads. The empirical correlations with equities we have seen for these times have been 54% for 2008, and 75% for 1998. Given this tendency for very high correlations during periods of market stress, we can conclude that the CEIOPS proposed correlation factor of 75% is reasonable.

C.61   We note the CRO Forum's support for this calibration based on a macroeconomic argument that spread and equity shocks often come together. We further note a stakeholder appeal for additional granularity

for cross country and rating weaker correlations. It is considered that the extra complexity this would bring would be inappropriate for the standard formula, and that the practical difficulties of having a plausible calibration would be high.

2.3 Other risk pairs

C.62   The above discussion gives a framework for the methods of analysis CEIOPS has performed to arrive at and justify its correlation coefficients. Similar analysis has been performed on many other risk pairs, in order to arrive at the correlation matrix for market risk shown in this final advice.

3. Interest rate up shocks

C.63   It may be argued that for some pairs of risks, the correlation between interest rates up and various risks would differ from those with interest rates down and the same risks. For example we may experience a positive correlation between a fall in interest rates and a fall in equities, but a rise in interest rates may be negatively correlated, or uncorrelated with a fall in equities.

C.64   For two risks, namely equity, and spread, we have observed very few historical data points where interest rates have risen substantially, and the other risk has fallen. This is partly a function of prevailing economic policy over the period of analysis; central banks tend to cut interest rates when other assets are shocked. Given this observation CEIOPS considers two sided stresses appropriate, with the interest rate up shock being set to zero.

C.65   For property risk against interest rate up risk, there is some evidence for a negative correlation between property fall and interest rate rise, however there is little data where there are 'extreme' property falls, together with 'extreme' interest rate rises; there is also an economic argument for a positive correlation. Taking this into account CEIOPS considers the correlation should be set to zero.