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How to use the standard model with own data?

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XARXA DE REFERÈNCIA EN ECONOMIA APLICADA

How to use the standard model with own data?

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Summary:

In this work discuss the use of the standard model for the calculation of the solvency capital requirement (SCR) when the company aims to use the specific parameters of the model on the basis of the experience of its portfolio. In particular, this analysis focuses on the formula presented in the latest quantitative impact study (2010 CEIOPS) for non-life underwriting premium and reserve risk. One of the keys of the standard model for premium and reserves risk is the correlation matrix between lines of business. In this work we present how the correlation matrix between lines of business could be estimated from a quantitative perspective, as well as the possibility of using a credibility model for the estimation of the matrix of correlation between lines of business that merge qualitative and quantitative perspective.

Keywords: Solvency II, Solvency Capital Requirement, Standard Model, correlation matrix.

1. AIMS AND SCOPE

In this paper we focus on the risk of inadequate premiums and reserves for non-life business. The standard formula[1] for this risk, and generally the standard model, can be used by entities using the parameters set for each line of business by the regulator as a *proxy* of market, or it can be adapted to the own risk profile through the estimation of new parameters based on the historical experience of the entity.

Why an entity would prefer to change the use of parameters submitted by the regulator for its own parameters? One possible reason can be derived from the fact that

[1] In this work we follow the standard formula proposed in QIS-5 for the risk of inadequate premiums and reserves. All parameters and correlations to which we refer is that there are considered.

the *proxy* overestimates the true risk profile of the entity, leading to an overestimate of the SCR than that resulting of the entity's own parameters. On the other hand, another reason for the estimation of parameters could come determined from the fact that the business structure of an insurance company is not adapted to the lines of business proposed by the regulator, so it should estimate the parameters necessary to obtain the corresponding SCR adjusting to the own business model.

On the last quantitative impact study (QIS) are presented various proposals for the estimation of specific standard deviations of premiums by line of business and standard deviations of reserves by lines of business. However do not give indications on what random variables must be considered for the estimation of the correlations *between lines of business* and other necessary correlation coefficients nor what methodologies should be used. In its place are predetermined correlation matrices, as a market *proxy*.

Our purpose is to shed a little light on this topic, defining what the regulator understands by *correlation matrix between lines of business*, and discuss how the matrix could be estimated, giving two approaches to this discussion, the methodology approach, i.e., which methods could be used to estimate of the *correlation matrix between lines of business*; and one more practical approach, that is, what information is relevant to the estimates, qualitative information or the quantitative.

In the following sections we discuss the methodology that could be used for the estimation of the correlations and what information would be relevant for these estimates.

2. BACKGROUND

Parallel to the emergence of the earliest quantitative impact studies began a series of streams of discussion on the implementation of the Solvency II directive, and

in general on the work of *Committee of European Insurance and Occupational Pension's Supervisor* (CEIOPS). Steffen (2008) highlighted the most marked aspects on Solvency II and CEIOPS work, and how the level of harmonization through the application of the principle of the *three pillars* between the different regulations of solvency in the European area should be increased. In this sense, Doff (2008) performed a Solvency II test comparing it with some criteria presented in Cummnis *et al.* (1994) and concluded that Solvency II met most of these criteria. He also pointed out that some of the problems that presented *pillar I*, as the inadequate incentives in the use of the standard formula, could be solved through the application and development of *pillar II* and *pillar III*.

Since the last QIS, the debate on the work of CEIOPS has mainly focused on the way in which the standard model for the SCR estimation should be implemented. Focusing on the *pillar I* of Solvency II, some authors have done some works on the estimation of the SCR of premium and reserves risk with the use of both proposals the standard and the internal model. Sandström (2007) reports the effect of considering a skewness coefficient in the SCR estimation. By presenting a number of examples, the author highlights differences in SCR estimations using calibrated and non-calibrated *Normal Power* distributions. Assuming *value-at-risk* and *tail value-at-risk* as risk measures, he finds that under the *Normal* distribution the SCR is underestimated.

Pfeifer and Straussburger (2008) deal with the problem of the SCR global aggregation formula in *Solvency II* for uncorrelated but dependent risks. They assume *value-at-risk* as a risk measure and several symmetric and asymmetric risk distributions and conclude that the overall aggregation formula underestimates the real SCR under some dependence structures, but may also overestimate it in some cases.

Savelli and Clemente (2009) compare the influence of company size on solvency requirements for premium risk under the QIS-3 standard formula and by adopting an internal approach based on copulas. They find that the standard approach overestimates solvency capitals in small companies. However, they only consider premium risk in the internal approach as the QIS-3 standard formula does not take reserve risk into account. Savelli and Clemente (2010) subsequently presented an alternative method based on the idea that the QIS-3 standard formula might be adjusted using the calibration factors proposed by Sandström (2007) and, thus, extended to consider highly skewed distributions. The authors also compare their results with those derived by copulas applying a hierarchical aggregation technique under several dependence structures and correlation assumptions.

Bermúdez *et al.* (2011) estimates the non-life underwriting SCR for premium and reserve risk sub-module by extrapolating the underwriting technical net result through simple linear regression technique for each line of business and then performing a Monte Carlo simulation of a multivariate random variable where each margin represents the behavior of the underwriting net result by line of business. The authors analyze the influence on the SCR estimation of the *correlation matrix by line of business*, and the dependence structures setting several copulas as well.

Embrechts *et al.* (2006) also analyzed aggregation concerning to operational risk solvency capital. However, none of these authors putted emphasis on the methodology for the estimation of the *correlation matrix between lines of business* necessary to perform the aggregation of risks and take into accounts the effects of diversification, both in the standard model proposal nor the internal model. A key element is therefore still pending of debate, the estimation of the correlations. Duverne Ledouit, (2009) already pointed this issue in a paper which discussed about the assessment of liabilities

derived from the valuation criteria of Solvency II and the IFRS (*International Financial Reporting Standards*), and identified discrepancies between the treatments of diversification across portfolios between the criteria of both standard-setting projects.

3. FORMULA STANDARD

The SCR corresponding to the risk premiums and reserves is calculated by means of a closed formula, which depends on a measure of volume, V, and an approximation of *mean-value-at-risk* with a significance level of 95% at a one year horizon, assuming a log-normal distribution of the underlying random variable, $\rho(\sigma)$.

$$SCR = \rho(\sigma) \cdot V.$$

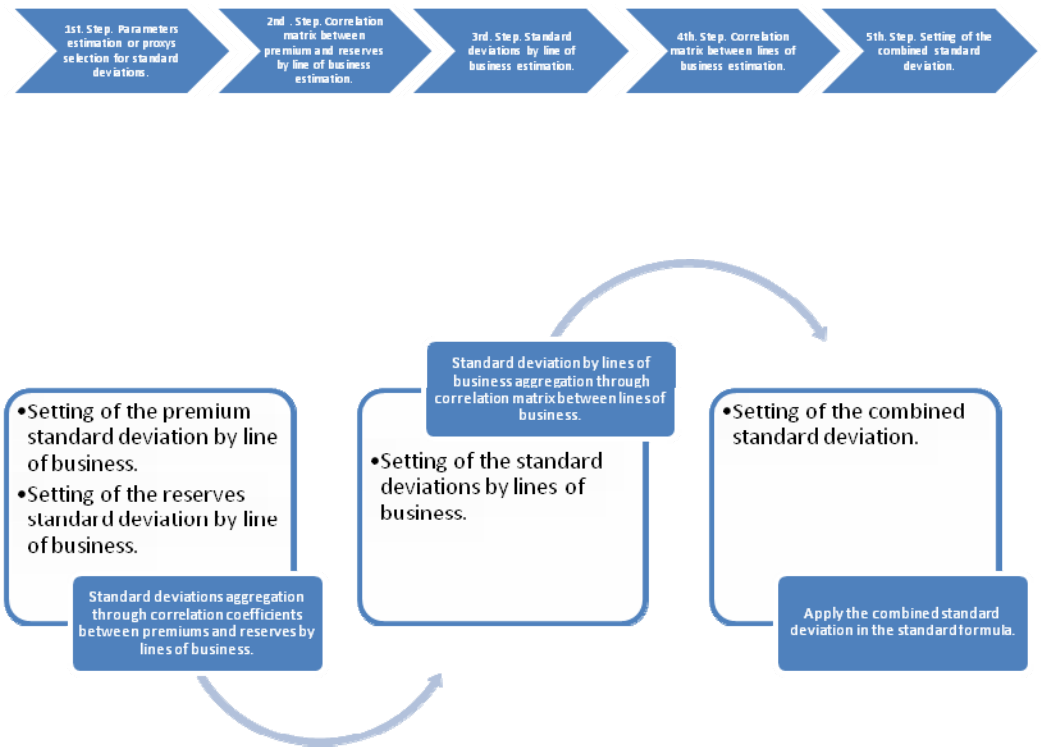
The expression $\rho(\sigma)$ depends on a parameter called *combined standard deviation* (σ). The standard formula, it is obtained, first, through the aggregation of the corresponding *standard deviation of the premium and standard deviation of reserves by lines of business,* taking into account the existing correlation between them, giving rise to what is known as *standard deviation by line of business.* Subsequently, through the aggregation of these and taking into account the existing correlation between lines of business lines, the *combined standard deviation* is obtained.

Therefore, an insurance company who intends to use the standard model with own parameters must follow the steps showed in Figure 1. First, it must obtain the values of the *standard deviations of premiums* by line of business and *the standard deviations of the reserves* by line of business. Secondly, these parameters should be added taking into account the correlation between random variables implied in its calculation to obtain a new parameter, the *standard deviations* by line of business. Finally, adding parameters corresponding to the *standard deviations* by line of business through the components of the *matrix of correlation between lines of business* is

obtained a single parameter, the *combined standard deviation*. To perform the aggregation of different deviations, the entity must choose between the use of correlation matrices proposed as a *proxy*, or estimate new correlation matrices.

An entity which decide to estimate new parameters should therefore define on the one hand the estimators needed for obtaining parameters corresponding to the different standard deviations and correlations, and on the other hand, the information necessary to make these estimates.

Figure 1. Estimation of parameters for the standard formula.



Source: own

In section 2, subsection 10th (SCR.10), of the last QIS are presented methodologies and some estimators which with an insurer can get standard deviations of the premiums and reserves based on its historical experience. Opposite way, as we

have said, there are not presented methodologies or estimators that could be used to obtain the necessary correlation matrices.

The first necessary step in order to estimate the *correlation matrix between lines of business* is to define which is the random variable considered in the standard formula, in order to be consistent with the model, estimators presented to obtain the rest of parameters and the expression $\rho(\sigma)$.

This expression, $\rho(\sigma)$ according to Gisler (2009) is derived from the consideration of a random variable, Z_i which is the implicit random variable in the standard formula for the premium and reserves risk.

$$Z_i = \frac{X_i \cdot P_i + Y_i \cdot R_i}{P_i + R_i}.$$

In this expression X_i and Y_i represent the loss ratio and the ratio of reserves in the *i-th* line of business, respectively; and P_i and R_i represent volume measures of premiums and reserves for the *i-th* line of business, respectively.

The random variable Z_i represents a mixture of two random variables, one representing the *premium risk* and another representing the *reserve risk*, by line of business. For more detail on the development of the standard formula see Gisler (2009).

In our view, considering the definition of Z_i, when Solvency II refers to the *correlation matrix between lines of business* refers to the correlation matrix between the random variable Z_i for all pairs of lines of business, while when referring to the coefficient of correlation between premiums and reserves refers to the correlation between random variables X_i and Y_i for all pairs of lines of business.

4. ESTIMATION OF THE MATRIX OF CORRELATION BETWEEN LINES OF BUSINESS

Once identified unambiguously the random variable implied in the standard model, the only thing that's missing is to propose how to estimate the *correlation matrix between lines of business* and the coefficients of *correlation between premiums and reserves*. In this section, we propose and discuss different alternatives on how to perform the estimation of the *correlation matrix between lines of business*. Taking into account their specificities, the discussion is also valid for the estimation of the coefficients of *correlation between premiums and reserves*.

The *correlation matrix between lines of business* and the *correlation coefficients between premiums and reserves* are presented as *proxies* of market. These estimates may be based on the expert judgment of the regulator. An insurance company might have knowledge through historical experience, and could make a judgment on what is the (cor) relationship between specific lines of business, as well as identify potential extraordinary events and take them into account, or not, in determining what is the estimate to be considered. A widespread approach is to determine qualitative grades on the relationship that two random variables (risks) has. In this way, they can be considered null correlations, low, medium or high. This seems to be the criteria adopted by the regulator. Two uncorrelated lines of business have a correlation coefficient equal to zero; two lines of business lowly related should have a correlation coefficient equal to a quarter. If the relationship is medium, the correlation coefficient would be a half, while if it is high, it should be three quarters.

An advantage of considering these expert judgments is that we can maintain some degree of stability in estimates over time. However, the degree of subjectivity is very high so the estimate is poor and subject to a high degree of error.

Another possibility is to make estimates based on quantitative criteria. In the quantitative impact studies or Solvency II do not refers to what type of correlation must be considered. A first decision is the choice of the type of correlation to estimate, linear correlation or rank correlation, for instance. Embretchs *et al.* (2002) discusses the implications of the use of linear correlations among random variables which are log-normally distributed. These authors show that, given certain values for the variances of two lognormal distributions, the correlation coefficient between the two random variables is given. The result shows how it is not always possible to build multivariate lognormal distributions, given some variances and an arbitrary correlation coefficient. This fact confirms that the linear correlation is not adequate measure of dependence outside the family of elliptic distributions. In the case of the correlation matrix presented as *proxy*, given that the model that is assumed for the calculation of the SCR is lognormal, it is in doubt that the correlation matrix shall be a linear correlation matrix.

On the other hand, the consideration of a quantitative methodology for both linear correlations and rank correlations, have some advantage, for instance, there are known estimators. Given a sample of empirical observations of the considered random variables the estimate of the correlation matrix can be easily obtained. A disadvantage of quantitative methods is that they are highly sensitive to sample's size and the values of the variables, causing instability in estimates over time as new observations are incorporated.

At this point, with the aim of overcoming the disadvantages pointed at the two previous approaches, we propose a third way for the estimation of the *correlation matrix between lines of business*, the estimate based on a credibility model. Trough this methodology, the estimate could incorporate the two sources of information available,

both the quantitative and qualitative information. Under a credibility model, the estimate of the correlation coefficient dependent, on the one hand, of the quantitative estimate that we would get from the experience of the entity itself, and on the other hand, qualitative estimation, which in this case we assume as the estimates submitted by the regulator. Greater or lesser importance assigned to each of these estimates depends on the *credibility factor*, α to determine in the credibility model used. In a simplified way, the formula of credibility for the coefficient of correlation (ρ) could take the following expression:

$$\rho = \alpha \cdot \rho_{own} + (1-\alpha) \cdot \rho_{QIS-5}$$

In this work we do not consider necessary to discuss different models of credibility that could be used in the estimation of the correlation coefficient. However, once chosen a credibility model and depending on the assumptions on it, the credibility model will provide us an estimator for the *credibility factor*. In general, the *credibility factor* depends on the variability of the data and/or the number of observations that are considered to obtain quantitative and qualitative estimates.

In this way, through the use of the credibility model we solve the two issues, the methodological and practical, that initially we were concerned about to estimate the parameters for SCR estimation derived from the standard model.

5. ESTIMATION OF THE SCR DEPENDING ON DIFFERENT ESTIMATES FOR THE MATRIX OF CORRELATION BETWEEN LINES OF BUSINESS

In this section we present an example in order to illustrate the effect that would have on the outcome of the SCR derived from the standard model taking into account different *correlation matrices between lines of business* obtained from: 1) the qualitative

information provided by the regulator, 2) quantitative information from the entity itself and 3) the credibility formula assuming various credibility factors.

The parameters corresponding to the *standard deviations of premiums and reserves* by line of business are those presented as a *proxy*, as well as the *correlation coefficients between risk premium and reserves.*

We used public information contained on the website of the Dirección General de Seguros y Fondos de Pensiones (DGSFP) for the calculation of volume measures necessary for the standard model and the estimation of the correlations. The data correspond to the historical aggregate volumes series for the period 2000-2010 of Spanish non-life market. Since information is presented in accordance with Spanish legislation, this has been reclassified taking into account the criteria that UNESPA established for the Spanish participating entities in the quantitative impact studies. Due to the information available, it only has been considered the first nine lines of business presented in the last QIS.

To get the estimation by the credibility model, previously we had made the quantitative estimate for available data, taking into account the way as we have defined the implicit random variable for the calculation of the *correlation matrix between lines of business* in section 2. The quantitative estimate has been done through the usual estimator for the linear correlation coefficient, the Pearson correlation coefficient. We assume that the qualitative estimation is the *correlation matrix between lines of business* presented by the regulator.

In order to see the impact that has on the SCR estimation the weight that is assigned to the credibility factor, and therefore, the quantitative and qualitative estimate, Table 1 shows the outcomes of the SCR derived from the standard model, under various credibility factor values.

Table 1. SCR * 2010 corresponding to the risk premiums and reserves according to the standard model for the Spanish market for non-life.		
Matrix of correlation between QIS LoB-5		6.66
Matrix of correlation between LoB, estimation of credibility	$\alpha. = 0.25$	6.50
	$\alpha. = 0.50$	6.34
	$\alpha. = 0.75$	6.19
Matrix of correlation between own LoB		6.02
* in billions of euros.		

6. DISCUSSION

Given the standard model aggregation structure of risks presented in the Solvency II directive, which follows a modular scheme of the different risks facing insurance entities, a key aspect in the estimation of the SCR are correlations between risks.

In the sub-module corresponding to the non-life underwriting premium and reserve risk, two matrices of correlation are considered, the *correlation matrix between the premium and reserve risk* and *correlation matrix between lines of business*.

In this paper we focus on the estimation of the *correlation matrix between lines of business* and the impact it has on the estimation of the SCR in the sub-module of risk. To this end we analyze the implicit random variable in the standard formula for calculation of capital requirements. This allows us to estimate the *correlation matrix between lines of business,* not necessarily in response to the same lines of business that the regulator proposes, at the time that we remain consistent with the standard model.

We present how by using credibility model is possible to make estimates for the *correlation matrix between lines of business lines* that incorporate both qualitative and quantitative information. In the example we have analyzed we obtained estimates that merge the *correlation matrix between lines of business* proposed by the regulator, which we believe has a qualitative character that comes from the *expert judgment* and

correlation matrix between lines of business from a quantitative approach based on a historical data set.

The results show the different SCR obtained depending on the credibility factors considered, ranging between the capital that would be obtained purely using the regulator's *correlation matrix between lines of business* and this that would be obtained purely with the empirical estimation resulting from the data.

The credibility models are widely used in the actuarial field for pricing. In our view, the use of these models can be useful also to make estimates of the relevant parameters in the estimation of the SCR, for those modules and sub-modules of risk where the directive proposes the use of *proxies* of market.

However, makes clear the need for estimators and methodologies to determine credibility factors coming, in general, determined by hypothesis related to variability arising from qualitative and quantitative information.

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