Abstract

In this doctoral dissertation, the problem of assessing the robustness of the Solvency II standard formula in estimating capital requirements and identifying dependencies between aggregated risk factors is addressed. The theoretical part discusses the Solvency II regulatory framework, the principles for determining the Solvency Capital Requirement (SCR), and the limitations of the variance–covariance formula with a fixed correlation matrix. The main objective of the thesis is to investigate the model risk of capital requirement aggregation under Solvency II, resulting from the uncertainty in the dependency structure between risk types, through the analysis of this uncertainty and the comparison of alternative aggregation models based on copulas and machine learning. The main goal has been decomposed into eight specific objectives. The main hypothesis formulated is as follows: *the uncertainty in the dependency structure between risk types generates significant model risk in the Solvency II standard formula, making the SCR results and diversification effects obtained from it sensitive to extreme dependency scenarios, whereas aggregation methods based on copulas and machine learning, which better capture real dependencies, provide more stable and adequate estimates.* The mathematical framework of risk aggregation is presented, including risk measures, diversification effects, and methods for modeling dependencies. The research objectives were pursued in two directions: developing methods for assessing the standard formula risk and methods for risk aggregation. Model risk was evaluated using four algorithms that enable analysis of the impact of changes in the correlation matrix, different dependency structures for the same correlation coefficient, and the significance of tail dependencies. The developed methods allow for a quantitative assessment of the formula's robustness to misspecification or incomplete specification of dependencies between risks. The concept of model risk was organized to include conceptual, implementation, and data-quality-related errors, as well as overfitting, and related to the Solvency II context. Quantitative measures for assessing model risk were characterized. The second research direction concerned modeling dependencies between risk types and methods of their aggregation. A vine copula approach was applied, allowing the decomposition of a multivariate distribution into bivariate Archimedean copulas. A method was proposed in which the multidimensional risk model, including marginal distributions and the dependence copula, is identified using deep neural networks. The role of machine learning methods in modeling complex, nonlinear dependencies between risks and their synergy with copula theory, enhancing the adequacy and robustness of SCR estimation, was discussed. The results indicate that describing dependency structures solely through the linear correlation coefficient is insufficient and may lead to inaccurate risk assessment. The use of copula-based methods allows flexible and precise identification of dependencies between risk types, including nonlinear and tail dependencies.