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Lysa Porth, Milton Boyd, Jeffrey Pai

Modeling Spatial Dependence and Optimal Retention for a Reinsurance Decision Model Under a Copula Framework

Lysa Porth[1], *Milton Boyd*[2] *and Jeffrey Pai*[3]

[1]University of Waterloo, Waterloo, Canada; lysaporth@gmail.com
[2]University of Manitoba, Winnipeg, Canada; Milton.Boyd@ad.umanitoba.ca
[3]University of Manitoba, Winnipeg, Canada; Jeffrey.Pai@ad.umanitoba.ca

Insurance losses due to adverse weather, including agricultural insurance, are often found to be spatially correlated across geographic regions, particularly for extreme events. If loss characteristics are non-normal with unique tail behaviour, ignoring nonlinear dependencies (correlation) can result in biased estimates of the risk profile for the agricultural crop insurance firm. This paper develops a fully integrated approach to spatial reinsurance questions, and maps the nonlinear dependencies of loss cost ratio's (LCR's, which are calculated as the ratio of indemnities to liabilities) across geographic regions in a country via a copula method. Using a comprehensive data set that covers the four largest crop insurance regions in Canada, which includes actual indemnities and liabilities, over 32 historical years, and across 155 crop types, several copula methods (i.e. Normal, t, Frank, Clayton, and Gumbel) are calibrated to a set of proposed actuarial risk measures, including surplus, survival probability, and deficit at ruin. This evaluation contributes to the body of literature that analyzes the importance of considering nonlinear dependencies, and further, recommends that copulas should be calibrated to the particular data set in order to fully consider the impact of copula choice, and reinsurance contract structure, on the calculated risk assessment. Ultimately, careful attention to calibration of copula methods to the particular data set will help to improve estimates of risk measures, financial requirements, and operational decision-making, which may lead to value creation for the adopting insurance firm.

A second objective of this paper is to investigate the optimal retention for a reinsurance decision model, employing efficient frontier analysis to determine the extent to which pooling is possible in agricultural crop insurance. This is considered by extending the framework set forth in Porth (2011), which develops a flexible reinsurance portfolio model with combinatorial optimization and a genetic algorithm. The calibrated copulas are applied to the reinsurance decision model, and the optimal allocation ratio (retention) is solved by considering the discrete grouping of crop risks in the portfolio that should be retained in the self managed reinsurance pool (i.e. the optimal extent to which pooling can be used), and the proportion of crop risks that should be ceded to private reinsurers, such that the variance to the joint pool is minimized. This evaluation shows that when nonlinear dependencies are considered via a copula approach, private reinsurance is needed in addition to pooling, if pooling is to be successful. This approach provides an innovative way for insurance firms to gain efficiencies, providing a lower-cost alternative for some crop insurance firms who currently do not purchase private reinsurance.