Academic Research Grants

Final Report

Introduction

The Canadian Institute of Actuaries (CIA) is dedicated to promoting and supporting academic research in the actuarial field. By funding research projects, the CIA plays a crucial role in advancing the understanding of complex actuarial issues that affect individuals, businesses and governments across Canada.

In this report, we present summaries of the research grants that the CIA has awarded over the past few years, covering a diverse range of actuarial topics such as intergenerational equity in the occupational pension sphere, developing a holistic risk framework for segregated funds involving hedging and investigating the impact of pension plan consolidation.

These research projects represent a significant contribution to the actuarial profession, and our funding has been instrumental in supporting this important work. By providing financial resources and support to researchers, we have helped to ensure that Canadians have access to the best possible financial advice and that their financial futures will be secure.

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Modern Metrics for Intergenerational Equity in Occupational Pensions

ARG Year	2018
Agreement Amount	$20,000
Principal Investigator(s)	Barbara Sanders
Institution(s)	Simon Fraser University

Objective of the Research Project

Intergenerational equity has been an important consideration in the management of social security programs and blocks of annuity business for a long time, but it has received relatively little attention in the occupational pension sphere until recently. As interest in risk-sharing pension designs continues to grow, intergenerational equity will become more and more important.

Proper dialogue around intergenerational equity is severely hindered by three factors: (1) the lack of uniform definitions and language, (2) practitioners' lack of familiarity with existing metrics for intergenerational equity, and (3) limited availability of modern, forward-looking metrics suitable for use with the stochastic projections that most large plans nowadays employ.

The objective of our research project was to fill the above-mentioned gaps by cataloguing relevant definitions of intergenerational equity, identifying existing metrics and developing new ones suitable for occupational pensions in stochastic applications.

Specifically, we planned to:

- conduct a comprehensive literature review spanning publications in the areas of actuarial science, economics, labour studies, finance, public policy and management, and ethics, in both English and French;

- gather input from key Canadian stakeholders (consulting actuaries, academics, policymakers and regulators) through a series of small roundtable meetings and personal interviews about their approach to taking into account intergenerational equity in pension plan management;

- develop suitable new metrics and demonstrate their use in one or more hypothetical plans through a stochastic simulation; and

- solicit feedback on our results at industry-oriented meetings (e.g., CIA Pension Seminar, SOA Annual Meeting).

Outcomes and Impact of the Research

In the course of this research project, we held three roundtables with practitioners, gave eight presentations at academic and industry conferences, produced one report (submitted to the CIA) and exposed at least three students to actuarial research.

The roundtables engaged 39 participants, including consulting actuaries, sponsors/stewards of large public and private sector pension plans, and actuaries involved with unions, as well as regulators and policymakers. The roundtables were extremely successful: most people we approached were eager to participate, the discussions were candid and non-adversarial, all contributions were thoughtful, and we were able to collect a variety of viewpoints and experiences. Formal participant feedback from the roundtables was very positive. Participants had the opportunity to discuss and differentiate the various meanings and aspects of intergenerational equity, reflect on how these manifest in actions taken in pension plan management, discuss the link between intergenerational equity and pension regulation (including the switch to post-solvency regimes in several provinces), explore the interplay between intergenerational equity and sustainability, and consider different metrics. The reflective exercise combined with an exchange of ideas has promoted clarity among individual actuaries and is expected to facilitate more effective dialogue with sponsors and policymakers.

Presentations by the research team were made at the following venues:

- International Congress of Actuaries 2018, International Actuarial Association, Berlin, Germany, June 2018
  - "Intergenerational Equity in Occupational Pensions: A Risk Management Perspective" (C. Gagné)
  - "Intergenerational Equity: Metrics for Conditional Indexation in Pension Plans" (L. Adam)

- Conférence régionale annuelle ARASQ 2018, Association de la retraite et des avantages sociaux, "Régime de retraite et équité intergénérationnelle: pistes de solutions pour un enjeu complexe et délicat," Pointe-au-Pic, Québec, Canada, September 2018 (C. Gagné)

- Vancouver Actuaries Club, "Intergenerational Equity: Metrics for Conditional Indexation in Pension Plans," Vancouver, BC, October 2018 (L. Adam)

- 2018 Society of Actuaries (SOA) Annual Meeting and Exhibit, SOA, Nashville, Tennessee, October 2018
  - "Evolution of Intergenerational Equity" (C. Gagné)
  - "Intergenerational Equity: Definitions and Metrics" (B. Sanders)

- 23rd International Congress on Insurance: Mathematics and Economics, "Intergenerational Equity in Occupational Pensions: How decision makers define and manage this risk," Munich, Germany, July 2019

In addition, undergraduate and graduate students at all three academic institutions (Simon Fraser, Université de Montréal and Université Laval) were involved in the research, including the literature review and the modelling of various metrics.

If you want to know more about this subject, contact the researcher: Barbara Sanders at [*bsanders@sfu.ca*](mailto:bsanders@sfu.ca)

A Holistic Approach to Hedging Optimization and Capital Requirements Calculation for Segregated Funds

ARG Year	2018
Agreement Amount	$20,000
Principal Investigator(s)	Frédéric Godin
Institution(s)	Concordia University

Objective of the Research Project

The original proposal outlined a plan to develop a hedging methodology for segregated funds policies (variable annuities) that takes into account the multiple sources of risk faced in practice: equity risk, interest risk, mortality risk, policyholder behaviour risk and basis risk.

Throughout the project, the scope slightly evolved; while we still considered a holistic risk framework for segregated funds involving hedging that takes into account all aforementioned risks, emphasis was instead put on risk measurement and allocation to the various risk sources. Indeed, in practice it is important to distinguish material risk drivers from those having a more moderate impact in order to determine where risk mitigation efforts are required. Our project thus used a Shapley decomposition method on profits and losses and Euler decompositions to allocate risk faced by an insurer issuing a segregated fund to the equity, interest and systemic mortality risk components (basis risk and policyholder behaviour being embedded in such categories). The scheme is quite flexible, as it could be straightforwardly adapted to other life insurance products, and it naturally incorporates hedging portfolios. This way, we can measure the risk drivers of an unhedged position first, and then quantify the percentage of risk removed from all risk classes by a hedging portfolio to measure its efficiency.

Outcomes and Impact of the Research

The main output of the research project is an academic paper that will be submitted to a high-quality academic journal (probably the *Scandinavian Actuarial Journal* or *ASTIN Bulletin*). We are working on final touch-ups before the submission. Once the paper is ready, we will present its content at renowned academic conferences (probably the Actuarial Research Conference, the International Congress on Insurance: Mathematics and Economics, or the Statistical Society of Canada). The content will also be presented at more minor conferences to which some of the authors are invited. Due to COVID-19, the project content has not yet been well disseminated, and we wish to give it more exposure through conferences and talks targeted at both academia and the industry.

The portion of the funding already received served to pay scholarship fees of a PhD student. This student conducted some helpful preliminary work on the topic (e.g., literature surveys, programming some simulations, etc.), but we realized that he was not fully ready to carry out such a complex project. Thus, although he is not a co-author of the paper we produced, he nevertheless gained valuable experience that helped him in his other doctoral research. We then onboarded another former student of Patrice Gaillardetz, Edwin Hon-Man Ng, to replace this student. Edwin was not remunerated for his work but is listed as a co-author due to his very fruitful participation in the project.

The research project was very successful in terms of results obtained, and it will most likely pave the way for multiple other publications on risk allocation and management in actuarial science (most likely in life insurance). Also, the pitfalls we encountered when trying to hedge interest risk will make an interesting paper in itself. Two of the authors (Patrice Gaillardetz and Frédéric Godin) will also leverage the research product obtained in their next Natural Sciences and Engineering Research Council of Canada (NSERC) application to highlight its significance.

If you want to know more about this subject, contact the researcher: Frédéric Godin at frederic.godin@concordia.ca

Efficient and Robust Maximum Likelihood Estimation of the Pareto Tail Index

ARG Year	2018
Agreement Amount	$20,000
Principal Investigator(s)	Alain Desgagné
Institution(s)	Université du Québec à Montréal

Objective of the Research Project

In this research project, we aim to design a new estimator of the Pareto tail index that makes practically no compromises between efficiency and robustness, with one of the smallest premiums to pay in terms of efficiency and one of the largest protections against outliers, combined with an asymptotic breakdown point of 50% (which is the proportion of outliers that the estimator can deal with without being contaminated). In practice, it means that the actuary will only need to provide the data set, with no parameters to set for the level of robustness. The latter will be chosen automatically by the method of estimation, resulting in a simplified and optimal process for any sample set, either in the presence or absence of outliers. A Monte Carlo analysis will also be conducted to compare the performance of our estimator with that of competitors. Finally, we intend to provide the computer code in an R package in order to maximize the impact of our research project and to facilitate its implementation in real actuarial applications.

Outcomes and Impact of the Research

The main impact of this project is the eventual publication of an original article in a peer-reviewed scientific journal. The article has already been submitted to the journal *TEST*, passed the first stage with the editor and is currently being reviewed by referees. The CIA grant is acknowledged in the paper as follows: "The financial support of the Canadian Institute of Actuaries is gratefully acknowledged."

I also intend to work on a new article that will be the Bayesian counterpart of robust inference using the Pareto distribution. This work will be inspired by this current project.

Another impact of the project is a graduate student's contributions to the research. So far, this student has received a $5,000 scholarship from the CIA grant. She was finishing all her classes this semester and completed the literature review. Since she came late to the project and was unable to contribute to the article, her project will be geared more towards data applications. In my opinion, the analysis of real data is somewhat neglected in the field of robustness, and I think that her project will fill a gap in this area.

If you want to know more about this subject, contact the researcher: Alain Desgagné at desgagne.alain@uqam.ca

Quantifying the Welfare Impacts of Pension Mergers

ARG Year	N/A
Agreement Amount	$19,800
Principal Investigator(s)	Jean-François Bégin
Institution(s)	Simon Fraser University

Objective of the Research Project

The occupational pension system is in a state of transition. On the defined benefit (DB) side, plan sponsors continue to adjust their plan's risk exposure. Some sponsors turn to investment solutions that enhance the plan's risk and reward profile, while others seek to transfer risk to insurers via annuity buy-ins and buy-outs or choose to adjust plan design elements. Jointly sponsored pension plans, shared risk plans and target benefit plans are examples of design innovations aimed at restructuring the balance of costs and risks in traditional DB plans.

An additional emerging solution is to adjust plans' fiscal and demographic profiles by expanding their membership and merging with other plans. For instance, at least two large Canadian public-sector DB plans opened their doors to new, unrelated employee groups, and three small-sized Canadian university plans decided to merge in recent years. A recent survey of 50 medium and large Canadian pension funds found that 38% have already consolidated assets and liabilities by merging with other plans, and 44% are considering doing so in the future (CIBC Mellon, 2021).

The purpose of the research project was to facilitate quantitative studies of the impact of pension plan consolidation by developing a framework that, for the first time, takes all relevant elements of pension plan operation into account. This framework included a realistic economic scenario generator, a stochastic mortality model that captures differences among subpopulations, a cost model with economies of scale, and a dynamic asset allocation methodology based on utility maximization. We constructed three groups of measures using this framework to quantify mergers' solvency and welfare impacts: plan-related risk measures assessing profits from an economic capital perspective, consumption-based metrics to understand the members' benefits, and contribution risk measures capturing the risk from the sponsor's viewpoint.

Outcomes and Impact of the Research

Using our framework, we considered two case studies: (1) a merger involving three small-sized Ontario universities of about 2,000 members each, and (2) a merger between a small Ontario corporate plan of about 1,000 members and a large Ontario plan of 50,000 members. Overall, we found overwhelming evidence of the benefits of merging. In the two cases considered in this study, we reported improvements from the plan's, the members' and the sponsor's perspectives. These gains were primarily explained by the reduction of the administrative and investment costs, better – more optimal – asset allocation strategies, an improved investment universe that allows for superior diversification, and better mortality pooling as the number of members increases post-merger.

Under some circumstances, the merger could simultaneously be considered advantageous when looking at one metric but disadvantageous when looking at another metric. This finding drew attention to the fact that mergers change the risk-reward tradeoffs of various stakeholders in different ways and allowed us to identify situations where this tension is magnified.

We believe this research project can significantly impact the actuarial profession as it provides clear guidance on evaluating the impact of pension mergers. The case studies we considered are empirically relevant, aligning well with current developments in the Canadian occupational pension sphere: see, for example, OPTrust and CAAT, as well as Ontario's new University Pension Plan.

In terms of output, the research project led to the recent submission of a paper entitled "To Merge or Not to Merge? On the Impacts of Pension Plan Consolidation" to the *North American Actuarial Journal*. This manuscript is a joint work with Barbara Sanders (colleague and co-investigator on this project) and Wenyuan Zhou (MSc in Actuarial Science, Simon Fraser University).

In addition to submitting the manuscript mentioned above, Barbara Sanders was recently invited to discuss the results of this project at the 2023 Annual Meeting of the Statistical Society of Canada in Ottawa, Canada.

In addition to Wenyuan Zhou, many undergraduate and graduate students received funding from this project to work on various components of the framework:

- Richard Li (BSc in Actuarial Science, Simon Fraser University) did a literature review on pension administrative and investment costs during the summer of 2020. He wrote an internal report explaining his findings, which was used as a basis for Section 2.3 of "To Merge or Not to Merge? On the Impacts of Pension Plan Consolidation."

- Yaqi Chen (BSc in Actuarial Science, Simon Fraser University) helped me create a new economic scenario generator used in "To Merge or Not to Merge? On the Impacts of Pension Plan Consolidation." Her work, completed in the summer of 2021, was also instrumental in publishing "On Complex Economic Scenario Generators: Is Less More?" in the ASTIN Bulletin in 2021.

- Wendy Xu (MSc in Actuarial Science, Simon Fraser University) actively worked on the mortality model used in "To Merge or Not to Merge? On the Impacts of Pension Plan Consolidation." Her work led to the submission of a paper to the *North American Actuarial Journal* entitled "Modelling and Forecasting Subnational Mortality in the Presence of Aggregated Data." This manuscript is being prepared for resubmission after some minor revisions.

If you want to know more about this subject, contact the researcher: Jean-François Bégin at jbegin@sfu.ca

Risk Measure-Based Precipitation Projections Impacted by Climate Change for Underlying Insurable Natural Catastrophes

ARG Year	2020
Agreement Amount	$20,000
Principal Investigator(s)	Mélina Mailhot
Institution(s)	Concordia University

Objective of the Research Project

In recent years, various model combination techniques have been considered in a wide range of applications. Our goal was to investigate the impact of model combination on the estimation of extreme precipitation and areal reduction factors (ARFs). ARFs allow for the calculation of precipitation over an area from a single point in the area. Moreover, we were interested in time variation of extreme precipitation and ARFs.

Outcomes and Impact of the Research

Model combination presents a potentially interesting tool for actuaries, as it allows for a way to obtain better estimates by combining the outputs of various methods. This could allow for improvement in both pricing and reserving forecasts.

Changes in extreme precipitation can also significantly impact actuaries' risk estimates for flooding and agricultural losses. A better modelling of these changes through model combination can improve projections of losses through tools such as the Actuaries Climate Risk Index (ACRI).

Our work will soon be submitted for publication in a special issue of the *Annals of Actuarial Science* (AAS) and will acknowledge the contribution of the Canadian Institute of Actuaries. The paper will be presented at the Canadian Statistics Student Conference (CSSC) in a special session, "Graduate Research in Actuarial Science."

This work represented a first publication as a PhD student for Sébastien Jessup, who will be presenting the paper at the CSSC.

If you want to know more about this subject, contact the researcher: Mélina Mailhot at melina.mailhot@concordia.ca

Transformation Forests for Auto Insurance Risk Modeling

ARG Year	2020
Agreement Amount	$16,500
Principal Investigator(s)	Hong Li
Institution(s)	University of Manitoba / University of Guelph

Objective of the Research Project

The objective of this research is to propose a flexible predictive framework based on a novel class of machine learning algorithm --- the transformation models. The proposed transformation-based insurance models combine the appealing features of both the traditional generalized linear models (interpretability, ability to generate the whole predictive distribution) and machine learning models (ability to incorporate complex dependency structure).

In particular, the proposed models have the following advantages: (1) they account for the potentially complex dependence structure of the insurance data considered; (2) they could estimate the whole (conditional) predictive distribution of the response variable (claim frequency, loss amount, etc), instead of just providing a point forecast; and (3) they have better interpretability than typical machine learning models.

The proposed models have wide potential applications. For example, the probabilistic forecasts allow the user to calculate various risk measures, such as variance, value-at-risk, and expected short falls. Furthermore, the inherited random forests structure can capture the highly non-linear dependencies between the response variable and numerous covariates, thus a desirable level of prediction accuracy can be guaranteed.

We aimed to apply the proposed models on two databases. The first database is the French model third-party liability (MTPL) insurance data set, which is included in the publicly available R package CASdatasets (http://cas.uqam.ca). The MTPL data set contains claim number of over 400,000 motor third-party liability policies, along with information of the driver, the vehicle, and the region, etc. The second database is Schedule P of the National Association of Insurance Commissioners, which includes firm-level run-off triangles of aggregated claims for major business lines of the U.S. property-casualty insurers, and is publicly available on https://www.casact.org/research/index.cfm?fa=loss_reserves_data.

Outcomes and Impact of the Research

We have successfully developed the transformation-based models described in our proposal. In particular, two models were developed, one focused on discrete response variables (claim frequency) and one focused on continuous response variables (loss amount, reserve, etc). The one change we made, compared to the proposal, is that we decided to use the simulation machine proposed by Gabrielli and Wuthrich (2018) to simulate the loss reserves. We did that because the simulation machine includes more covariates, with which we can better evaluate the predictive power of the proposed model.

We have submitted a final report to the CIA. We changed the title to "Transformation Models for Insurance Risk Modeling" because the loss reserve is no longer related to auto insurance. We plan to submit this paper to the Journal of Risk and Insurance after some supplementary analyses (robustness tests, comparisons to more existing methods) are done. Furthermore, we plan to present this work in the 25th (2022) International Congress on Insurance: Mathematics and Economics.

We believe that, besides its academic value (and a potential publication in an actuarial science or insurance journal), this project benefits practitioners by providing them with an alternative model for rate making and reserving for various insurance products. As mentioned above, the proposed models, to the very least, could serve as a supplement to the existing GLMs and machine learning methods, and could be used to evaluate the predictive results generated by these models.

During the term of this project, an undergraduate research assistant at the University of Manitoba, Zheyu Chen, was hired. Zheyu helped a lot with data preparation and model implementation. Although I had to stop hiring her in the spring of 2021 as I was about to terminate my job at the University of Manitoba and all grants were frozen, I am glad that the RA experience had motivated Zheyu to pursue an academic career and has got offers from many master's

programs worldwide. She has accepted an offer from a top Actuarial Science master's program and is planning to pursue her Ph.D. studies afterwards.

Reference

Gabrielli and Wuthrich (2018) An individual claims history simulation machine. *Risks*, 6(2).

If you want to know more about this subject, contact the researcher: Hong Li at lihong@uoguelph.ca

The Canadian Institute of Actuaries (CIA) is the qualifying and governing body of the actuarial profession in Canada. We develop and uphold rigorous standards, share our risk management expertise and advance actuarial science to improve lives in Canada and around the world. Our more than 6,000 members apply their knowledge of math, statistics, data analytics, and business in providing services and advice of the highest quality to help Canadian people and organizations face the future with confidence.