Drake Risk and Insurance Workshop on Catastrophe Risk
Drake University, USA
February 19, 2021
https://catastropheinsuranceworkshop.wp.drake.edu/

Abstracts

8:50–10:20 Invited Session: "*Modeling Insurance Risk*"
Chair: **Lisa Gardner** (Eastern Kentucky University)

The Discriminating (Pricing) Actuary

Edward (Jed) Frees, University of Wisconsin-Madison and Australian National University,
Email: jfrees@bus.wisc.edu
Fei Huang, UNSW Sydney

The insurance industry is built on risk classification, grouping insureds into homogeneous classes. Through actions such as underwriting, pricing and so forth, it differentiates, or discriminates, among insureds. Actuaries have responsibility for pricing insurance risk transfers and are intimately involved in other aspects of company actions and so have a keen interest in whether or not discrimination is appropriate from both company and societal viewpoints. This paper reviews social and economic principles that can be used to assess the appropriateness of insurance discrimination. Discrimination issues vary by the line of insurance business and by the country and legal jurisdiction. This paper examines social and economic principles from the vantage of a specific line of business and jurisdiction; these vantage points provide insights into principles. To sharpen understanding of the social and economic principles, this paper also describes discrimination considerations for prohibitions based on diagnosis of COVID-19, the pandemic that swept the globe in 2020.

Insurance discrimination issues have been an important topic for the insurance industry for decades and is evolving in part due to insurers' extensive use of *Big Data*, that is, the increasing capacity and computational abilities of computers, availability of new and innovative sources of data, and advanced algorithms that can detect patterns in insurance activities that were previously unknown. On the one hand, the fundamental issues of insurance discrimination have not changed with Big Data; one can think of credit-based insurance scoring and price optimization as simply forerunners of this movement. On the other hand, issues regarding privacy and use of algorithmic proxies take on increased importance as insurers' extensive use of data and computational abilities evolve.

Keywords: Actuarial fairness, disparate impact, proxy discrimination, unisex classification, credit-based insurance scores, price optimization, genetic testing, big data, COVID-19

Paper available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3592475

Modeling Severity and Measuring Tail Risk of Norwegian Fire Claims

Vytaras Brazauskas, University of Wisconsin-Milwaukee, Email: vytaras@uwm.edu

The probabilistic behavior of the claim severity variable plays a fundamental role in calculation of deductibles, layers, loss elimination ratios, effects of inflation, and other quantities arising in insurance. Among several alternatives for modeling severity, the parametric approach continues to maintain the leading position, which is primarily due to its parsimony and flexibility. In this paper, several parametric families are employed to model severity of Norwegian fire claims for the years 1981 through 1992. The probability distributions we consider include: generalized Pareto, lognormal-Pareto (two versions), Weibull-Pareto (two versions), and folded-t. Except for the generalized Pareto distribution, the other five models are fairly new proposals that recently appeared in the actuarial literature. We use the maximum likelihood procedure to fit the models, and assess the quality of their fits using basic graphical tools (quantile-quantile plots), two goodness-of-fit statistics (Kolmogorov-Smirnov and Anderson-Darling), and two information criteria (AIC and BIC). In addition, we estimate the tail risk of "ground up" Norwegian fire claims using the value-at-risk and tail-conditional median measures. We monitor the tail risk levels over time, for the period 1981 to 1992, and analyze predictive performances of the six probability models. In particular, we compute the next-year probability for a few upper tail events using the fitted models and compare them with the actual probabilities.

Note: This is a joint work with Andreas Kleefeld (Brandenburg University of Technology).

The Actuaries Climate Index (ACI) and Trends in US Catastrophes

Steve Kolk, Kolkulations LLC, Email: kolkulations@gmail.com

Did you know that the United States had a record number of Billion-dollar disaster (BDD) events in 2020? Twenty-two BDD events smashed the previous us record of 16. This presentation will use the ACI and illustrate how to dissect trends in catastrophic US billion-dollar disasters with three STastical RUles of Thumb (aka StRuTs). Come and learn about:
StRuT #1 - how a Waterfall graph can discern which ACI "Cat" trend signals are the strongest,
StRuT #2 - how the LOESS method finds the trend signal in very noise catastrophe data, and
StRuT #3 - a simple Statistical Rule of Thumb to find trend signals in noisy "Cat" data

10:30–12:00 Invited Session: "*Flood Risk*"
Chair: **Fan Yang** (University of Waterloo)

The Frequency of Flood Events Across the Central United States and Climate Change
Gabriele Villarini, University of Iowa, Email: gabriele-villarini@uiowa.edu

The frequency of flood events has been increasing across large areas of the central United States since the second half of the 20th century. Little is known about what is driving these changes, and the fundamental question we ask ourselves is: why?

Using an observation-driven approach, we develop a statistical framework to attribute the changes in the frequency of flood events to changes in the climate system and to land use / land cover. Results indicate that climate-related variables play a major role in explaining the changes in the frequency of these events. Furthermore, we highlight the role of changes in the frequency of weather systems associated with heavy precipitation across the central United States in response to human-induced climate change.

The aim of this presentation is to provide insights into the possible reasons responsible for the changes in the frequency of flood events, providing basic information that may enhance our capability of predicting and projecting these changes.

Peer-to-Peer Risk Sharing with an Application to Flood Risk Pooling
Runhuan Feng, University of Illinois at Urbana-Champaign, Email: rfeng@illinois.edu

In an increasingly sophisticated sharing economy, the concept of risk sharing has been popularized with the rise of peer-to-peer insurance at a micro level and catastrophe risk pooling at a macro level. This work aims to provide a novel theoretical framework for the understanding of peer-to-peer network structure in risk sharing.

In contrast with classic centralized risk sharing, the peer-to-peer risk sharing framework is proposed to take into account pair-wise exchanges. The presented framework aims to develop risk allocation mechanisms that are structurally decentralized, Pareto optimal, and mathematically fair. In addition, a tiered hierarchical generalization is also constructed to improve computational efficiency. As an illustration, these techniques are applied to a flood risk pooling example. Flood risk is known to be difficult to cover in practice, which contributes to the stagnant development for a private insurance market. It is shown that peer-to-peer risk sharing techniques provide an economically viable alternative to traditional flood policies.

A Global Flood Risk Modeling Framework Built with Climate Models and Machine Learning

David Carozza, Université du Québec à Montréal
Mathieu Boudreault, Université du Québec à Montréal, Email: boudreault.mathieu@uqam.ca

Large scale flood risk analyses are fundamental to many applications requiring national or international overviews of flood risk. While large-scale climate patterns such as teleconnections and climate change become important at this scale, it remains a challenge to represent the local hydrological cycle over various watersheds in a manner that is physically consistent with climate. As a result, global models tend to suffer from a lack of available scenarios and flexibility that are key for planners, relief organizations, regulators, and the financial services industry to analyze the socioeconomic, demographic, and climatic factors affecting exposure. Here we introduce a data-driven, global, fast, flexible, and climate-consistent flood risk modeling framework for applications that do not necessarily require high-resolution flood mapping. We use statistical and machine learning methods to examine the relationship between historical flood occurrence and impact from the Dartmouth Flood Observatory (1985-2017), and climatic, watershed, and socioeconomic factors for 4734 HydroSHEDS watersheds globally. Using bias-corrected output from the NCAR CESM Large Ensemble (1980-2020), and the fitted statistical relationships, we simulate one million years of events worldwide along with the population displaced in each event. The main value of this global flood model lies in its ability to quickly simulate realistic flood events at a resolution that is useful for large-scale socioeconomic and financial planning, yet we expect it to be useful to climate and natural hazard scientists who are interested in socioeconomic impacts of climate. During the presentation, we discuss potential applications of the model, notably for the international (re)insurance industry, including global flood hazard and risk maps, the impacts of El Nino / Southern Oscillation on flood risk and the contribution of climate (change) and urbanization to flood risk over the past 40 years.

13:10–15:10 Contributed Parallel Session: "*Valuation and Managing Insurance Risk*"
Chair: **Jianxi Su** (Purdue University)

Pareto-optimal Reinsurance with Default Risk and Solvency Regulation
Tim J. Boonen, University of Amsterdam, Email: t.j.boonen@uva.nl
Wenjun Jiang, University of Calgary

This paper studies an optimal reinsurance problem of Pareto-optimality when the contract is subject to default of the reinsurer. We assume that the reinsurer can invest a share of its wealth in a risky asset and default occurs when the reinsurer's end-of-period wealth is insufficient to cover the indemnity. We show that without the solvency regulation, the optimal indemnity function is of excess-of-loss form, regardless of the investment decision. We model solvency regulation as a constraint on the probability of default. Under solvency regulation, by assuming the investment decision remains the same as in the unconstrained solution, the optimal indemnity function is derived element-wisely. Partial results are given when the indemnity function and investment decision are jointly constrained by the solvency regulation. Numerical examples are provided to illustrate the implications of our results and the sensitivity of the solutions to the model parameters.

Keywords: Reinsurance, Pareto-optimality, default risk, investment, solvency regulation

Actuarial and Financial Valuation of CAT Bonds
Saeid Safarveisi, KU Leuven, Email: saeid.safarveisi@kuleuven.be
Hirbood Assa, Liverpool University
Jia Shao, Coventry University

Among different types of insurance-linked security instruments existing in capital markets, CAT bonds are important for insurance companies. Such a contract includes both financial and actuarial risks, making their valuation procedure quite complicated from a theoretical perspective. The financial valuation of CAT bonds is based on the idea of arbitrage-free pricing and a risk-neutral measure approach. In this paper, we provide a valuation based on the actuarial methodology in which the best estimate of discounted loss plus a risk margin are computed under the physical measure. To do so, we introduce the variance premium principle and achieve a closed-form formula for the CAT bond price. As it is impossible to determine the physical probability distribution associated with the aggregate losses explicitly, we apply the Monte-Carlo simulation technique. Our analysis shows that the CAT bond price calculated by the actuarial method is higher than the financial price.

Keywords: Physical measure, risk-neutral measure, martingale, Monte-Carlo simulation, arbitrage-free pricing, catastrophe bonds

The Gradient Allocation Principle based on the Higher Moment Risk Measure

Fabio Gómez, Universidad del Rosario, Email: fabioa.gomez@urosario.edu.co
Qihe Tang, UNSW Sydney

According to the gradient allocation principle based on a positively homogeneous and subadditive risk measure, the capital allocated to a sub-portfolio is the Gâteaux derivative of the underlying risk measure at the overall portfolio in the direction of the sub-portfolio. We consider the gradient allocation principle based on the higher moment risk measure. In doing so we prove that this risk measure is Gâteaux differentiable and derive an explicit expression for the Gâteaux derivative. Then we illustrate how to compute this expression under some specific distributional assumptions.

Keywords: Gradient allocation principle, higher moment risk measure, Gâteaux derivative, multivariate distributions

Indifference Pricing of Insurance-Linked Securities

Haibo Liu, UNSW Sydney, Email: haibo.liu1@unsw.edu.au
Qihe Tang, UNSW Sydney
Zhongyi Yuan, The Pennsylvania State University

Insurance-linked securities (ILS) have recently become an important risk transfer mechanism to help insurers and reinsurers transfer catastrophe risks to the capital market. We employ the utility indifference approach to establish a pricing framework for a representative agent who trades an ILS with payoff linked to an insurance risk process and a reference rate process. The agent, while investing in a financial market composed of traditional financial instruments, discovers her indifference prices of the ILS by weighing the ILS trade on her exponential utility. The problem has been studied extensively, but mainly in one-period models that are best suited for zero-coupon instruments. In view of the prevalence of ILS having interim payments, we extend the study to a multi-period model by working with time 0 equivalent values and solving a multi-period optimization problem. We offer insights into issues such as coherence and time consistency of the ask and bid indifference prices obtained. Finally, we conduct a sensitivity analysis of the prices against certain risk parameters.

13:10–15:10 Contributed Parallel Session: "*Catastrophe Risk in a Changing World*"
Chair: **Tianxiang Shi** (Temple University)

COVID-19, the Mother of All Catastrophes: How to Manage Its Economic Risk?
Hirbod Assa, Kent Business School, Email: assa.hirbod@gmail.com

The economic impact of the recent COVID-19 outbreak has reached a point that nobody would have imagined a year ago. Except for a very few, all countries in the world have experienced dramatic economic downturn. The major question though is that how the societies would be able to manage such macro-economic risks. In particular, are there any, or can there be any insurance solution for that. In this talk I will be reporting on some of the current joint research on macroeconomic risk management in relation to systematic risk like COVID-19. In particular, I want to look at the role of common shock, ex-post insurance policies, social reinsurances on the unemployment, and also supply impacts of COVID in the UK. This was one also can characterize the characteristics of the macro-risk-management as a new area to be studied.

How Do Households Respond to Public Program Reforms? Evidence from the U.S. National Flood Insurance Program
Benjamin L. Collier, Temple University, Email: collier@temple.edu
Tobias Huber, Ludwig-Maximilians-Universität München
Johannes G. Jaspersen, Ludwig-Maximilians-Universität München
Andreas Richter, Ludwig-Maximilians-Universität München

How households will respond to reforms of public insurance programs is unclear given recent behavioral findings on consumers' insurance choices. We examine the insurance decisions of an extremely vulnerable group in the U.S. National Flood Insurance Program. Severe repetitive loss (SRL) properties account for only 1% of policies but 25–30% of flood claims. Congress passed a reform that phases out the premium subsidies offered to this group over several years such that their premiums will eventually equal their contract's actuarially fair rate. We measure the effect of the reform using difference-in-differences estimation on a panel of over two million policy-year observations. We find that about one fourth of SRL property owners decided to stop insuring in response to the reform. The reform did not meaningfully affect the coverage limit choices of households that continued to insure. Curiously, the observed effect on nonrenewal begins after the law was ratified but before it was implemented. Our findings thus seem in contrast to canonical and most common behavioral theories of insurance demand. We discuss potential alternative decision-making explanations of our results and are able to rule out some of them. Our findings add to research on public policy design and offer behavioral insights into insurance demand.

Keywords: Public programs, public policy design, insurance choices

The Changing Spatial Dependence in Flood Risk: A Loss Occurrence Study in the United States

Rob Erhardt, Wake Forest University, Email: erhardrj@wfu.edu
Mathieu Boudreault, Université du Québec à Montréal
David Carozza, Université du Québec à Montréal
Kejia Yu, Wake Forest University

Flood represents one of the costliest and most disruptive natural disasters in the United States, and the economic losses from flooding are trending upward. While this trend is known to be driven primarily by an increasing population and increasing wealth exposure, climate change is also impacting flood risk in more subtle ways. We merge data on economic flood losses, historical climate, census population, and geological characteristics to explore trends in the spatial dependence of economic flood loss occurrence across 292 hydrobasins from 1979-2018 in the United States. Using an autologistic statistical model for flood loss occurrence and controlling for known covariates, we quantify climate drivers of flood risk occurrence and show empirically that measures of spatial clustering and dependence have been decreasing over the study period. Through a simulation study with our statistical model, we document how our changing climate is a partial cause of this trend.

Creating a Private Flood Insurance Market: A Close-up Review of the North Carolina Rate Bureau Plan Developed Amid Market Challenges

David D. Evans FCAS, MAAA – Milliman, Inc.
Rebecca R. Williams ACAS, MAAA – North Carolina Rate Bureau, Email: beckyrwilliams@gmail.com
Lorilee A. Medders, PhD, Appalachian State University

The National Flood Insurance Program (NFIP) has been virtually the only choice for residential flood insurance coverage since the 1960s. Despite significant flood risk, the NFIP experiences low participation rates among homeowners – somewhere between 5 and 15 percent of homes – and remains in a large financial deficit based on its risk (and loss) portfolio of homes it has insured. Several states have explored alternative options, seeking a sustainable primary insurance market for flood.

In early 2020, the North Carolina Department of Insurance approved a private flood insurance program available for use or adoption by the more than 100 companies of the North Carolina Rate Bureau (NCRB). This research examines this new North Carolina flood insurance program – how it was developed and what makes it unique to other flood insurance programs across the country. The program's unique features can be found in both the coverage possibilities and the rating plan employed.

In addition to reviewing the NCRB Plan, the authors share multiple product and market challenges faced by insurers and regulators due to the complexity of the flood peril. Due to these challenges, consumers in most states have fewer flood insurance options available than they do for other property insurance, such as homeowners coverage. The researchers additionally assess various regulatory approaches states have taken to promote consumer choice for flood insurance. Finally, the work discusses next steps for flood insurance in the United States, and what steps can be taken to promote the use of flood insurance for protecting many Americans' most valuable asset – the home.

Key References

- Born, P. & Klein, R. (2019). Privatizing flood insurance in the United States: Options, challenges and pitfalls. Working paper.
- Horn, D. (2019). National Flood Insurance Program: The Current Rating Structure and Risk Rating 2.0, Congressional Research Service.
- Marlett, D., Medders, L. & Lattimore, C. (2020, September 4). An evaluation of the North Carolina Rate Bureau's Residential Flood Insurance Program. Report submitted to the North Carolina Realtors Association.
- North Carolina Rate Bureau. (2019, September 19). North Carolina Residential Flood Proposal to the North Carolina Department of Insurance.

15:20–17:20 Invited Session: "*Emerging Risks*"
Chair: **Yi Lu** (Simon Fraser University)

Can the Cyber Insurance Market Improve Cybersecurity?
Tatyana Bolton, R Street, Email: tbolton@rstreet.org

Insurance plays a critical role in a functioning market. Likewise, cyber insurance could help the cyber ecosystem become more secure, but only if it is functional. But can it, in fact, be all that it claims? And can it function? Insurance can protect people and an organization's technical systems from damage cyber attacks may cause through a system that quantifies risk, provides emergency protection, and distributes losses. But today, the cyber insurance market lacks the specificity and the answered questions that all actuaries crave. So, while, in effect, our market is based on flawed logic and inadequate data, will it survive to be the cybersecurity progress-maker that some envision? Or will it flame out like the European market before it has a chance to live up to these lofty ambitions? I will discuss the fundamentals of cybersecurity and why a cyber insurance market could help solve some fundamental problems, the challenges holding the insurance market back, and some examples where the cyber insurance market has been tested.

Capturing the Complexity of Cyber Risk
Scott Stransky, AIR Worldwide, Verisk Cyber Solutions, Email: sstransky@air-worldwide.com

Cyber risk modeling helps (re)insurers understand their loss potential from cyber events before they occur. This session will discuss how cyber risk modeling can use a data-driven approach that leverages machine learning and stochastic simulations. Learn how cyber risk models can deliver insights about the likelihood of cyber incidents and their potential financial impacts to a company's book of business.

Data Breach CAT Bonds: Modeling and Pricing

Maochao Xu, Illinois State University, Email: mxu2@ilstu.edu

According to the 12th Emerging Risks Survey conducted by the Society of Actuaries in 2018, cybersecurity threat has become the top emerging risk. In particular, the data breach risk has become and will continue to be a big problem due to the enormous network activities. The monetary loss incurred by data breaches is also substantial. IBM reported that in year 2019, the global average cost for a data breach was $3.92M, and the US was the most expensive country with each event $8.19M. According to NetDiligence report in 2018, the total breach cost for the claims submitted in years 2013-2017 was $721M, with the largest was $60M. Catastrophe (CAT) bonds as one of a number of innovative risk transfer products have emerged as an alternative to traditional insurance and reinsurance products. They are designed to transfer specific risks from insurance/reinsurance companies to investors. However, there is little study in the literature to explore the possibility of transferring the data breach risk via CAT bonds.

In this talk, we discuss how to design and price data breach CAT bonds for the current market. In particular, we study the extreme value theory and time series approaches for modeling the related risks. We also present a simulation study for determining the bond prices and cash flows. Our study shows that the data breach bond can be a promising financial product for transferring the cyber risks.

Catastrophe Risk Management

Han Li, Macquarie University
Qihe Tang, UNSW Sydney, Email: qihe.tang@unsw.edu.au
Zhongyi Yuan, The Pennsylvania State University

Recent decades have been marked by an unprecedented surge in the frequency and severity of catastrophes, both natural and man-made, all of which produce widespread destruction on the environment, economy, and society. In particular, they have significantly altered the financial landscape of the insurance industry. In this talk I will present two of my recent works as an academic response to catastrophe risk: (1) Pricing CAT bonds; (2) Joint extremes in climate and mortality.