AARMS CRG - Workshop on Financial Mathematics and Actuarial Science
August 6, 2021

Abstracts

Real Options, Risk aversion, and industry 4.0

Matt Davison

Western University, Canada

Abstract: There is an apparent paradox built into the heart of quantitative finance. In Portfolio optimization we penalize riskier portfolios, perhaps through the use of a risk averse utility function. But in options pricing we observe that the value of a long position in an option increases with the volatility of the underlying asset. So which is it? Do we want volatility or not?

Real options applies financial mathematics thinking to problems arising other business or management settings. So an enterprise may be considered as a portfolio of projects, the value of which is decreasing in portfolio volatility. Each project may be a real option on some kind of uncertain driver, the value of which increases in volatility. However, real options thinking is often criticized for ignoring real business constraints which greatly damp the value of volatility for a given project.

The Industry 4.0 concept describes the current computerization (ai, data science, internet of things, 3D printing, etc) of industry. One implication of Industry 4.0 may be relax the weight of some volatility value killers on projects and as such bring our financial paradox into starker contrast.

I will illustrate this talk with a very simple set of examples integrating manufacturing and finance through a real options lens.

The Costing of Guaranteed Basic Income in Canada

Louis Doiron

University of Prince Edward Island, Canada

Abstract: In this session you will learn about the design and costing of a Guaranteed Basic Income program in Canada and of its potential challenges as well as the roles of actuaries in the various phases of its implementation.

Conditional Non-Lattice Integration, Pricing and Superhedging

Sebastian Ferrando

Ryerson University, Canada

Abstract: Closely motivated by financial considerations, we develop an integration theory which is not classical i.e. it is not necessarily associated with a measure. The base space, denoted by $\mathcal{S}$ and called a trajectory space, substitutes the set Ω in probability theory and provides a fundamental structure via conditional subsets $\mathcal{S}_{(S,j)}$ that allows the definition of conditional integrals. The setting is a natural by-product of no arbitrage assumptions that are used to model financial markets and games of chance (in a discrete infinite time framework). The constructed conditional integrals can be interpreted as required investments, at the conditioning node, for hedging an integrable function, the latter characterized a.e. and in the limit as we increase the number of portfolios used. The integral is not classical due to the fact that the original vector space of portfolio payoffs is not a vector lattice. In contrast to a classical stochastic setting, where price processes are associated with conditional expectations (with respect to risk neutral measures), we uncover a theory where prices are naturally given by conditional non-lattice integrals. One could then study analogues of classical probabilistic notions in such a non-classical setting, the paper stops after defining trajectorial martingales the study of which is deferred to future work.

Bridging Epidemiological and Actuarial Models: The Case of COVID-19

José Garrido

Concordia University, Canada

Abstract: The current COVID-19 pandemic has prompted actuarial researchers to reflect on current issues that the industry faces and to find ways to tackle them. While there has been extensive research on the transmission dynamics in the epidemiology and medical literature, traditional actuarial work has largely focused on mortality and morbidity rates using classic frequency and severity analysis. Actuarial life tables and mortality models lack flexibility and robustness to describe the rapidly changing environment during a pandemic. To that end, we explore the epidemiology literature and combine some of the commonly used models with actuarial methodologies. The presentation concludes with case studies using the actual COVID-19 data set and another application of compartmental models in the subject of allocation of resources during a pandemic. In particular, we project demand for critical medical resources and use actuarial concepts of capital allocation to optimally stockpile resources prior to a pandemic and to ration limited existing resources during a pandemic.

Co-authors: Runhuan Feng , Longhao Jin, Lifeng Zhang (University of Illinois Urbana-Champaign) and Sooie-Hoe Loke (Central Washington University)

Network Topology As A Tool To Understand Market Structure

Antoine Kornprobst

Western University, Canada

Abstract: Our study aims at constructing tools designed to examine the structure of an equity market from the perspective of network theory. In this framework, the sector sub-indices of an equity index are the nodes and the edges between them exist when their realized Pearson correlation over a rolling window of historical data exceeds a chosen threshold. The topological properties of the network thus created, including total number of edges, number of connected components and homotopy group, are then associated to financial quantities like the VIX volatility index in order to understand and interpret market structure from this novel point of view. In the theoretical part of our study, we first determine an optimal size for the rolling window, after taking into consideration the amount of Type I and Type II errors that we wish to tolerate, and then we test our approach in a controlled environment by using simulated returns under various scenarios. We then conduct a numerical analysis of the historical time-series of the eleven sector sub-indices of the SP500 index over the past fifteen years to demonstrate the relevance and usefulness of this original framework.

Path Generation Methods for Valuation of Large Variable Annuities Portfolio

Kai Liu

University of Prince Edward Island, Canada

Abstract: Variable annuity (VA) is an investment-linked long-term insurance product and represents an important source of retirement income in many countries. Accurate valuation of large VA investment portfolios is an important task for insurance companies. However, variable annuities usually have complicated benefits, depending on the death risk of the policyholder and financial market risks. Therefore, their value is usually estimated by Monte Carlo (MC) simulation. This is computationally intensive. One of the main bottlenecks of intensive computing is to simulate a large number of sample paths from dynamic asset models. In this research, we proposed and analysed different quasi-Monte Carlo (QMC) path generation methods (PGM) for valuing large variable annuity investment portfolios. We argue that different PGMs have no effect on the

MC but have significant effect for QMC pricing efficiency. A lot of numerical experiments have been carried out. Our numerical results show that, although with different accuracy, all PGMs produce more accurate estimates at the policy level and portfolio level than standard MC simulations. Interestingly, the optimal PGM may be different when considering different scenarios.

Hierarchical Random Effects Model for Insurance Pricing of Vehicles Belonging to a Fleet

Yang Lu

Concordia University, Canada

Abstract: We propose a hierarchical random effects count data model for the posterior insurance ratemaking of vehicles belonging to a fleet, by allowing random effects for fleet, vehicle, and time. We derive a simple and tractable closed form ratemaking. We estimate the corresponding econometric model and compute insurance premiums according to the past experience of both the vehicle and the fleet.

Bachelier model revisited: modelling and option pricing

Alexander Melnikov

University of Alberta, Canada

Abstract: Mathematically the Bachelier (1900) model for stock price evolution is represented as a sum of a Brownian Motion and an absolutely continuous drift. One of the main disadvantages of such a model is a possibility for stock prices to take negative values. To overcome it Samuelson (1965) proposed to transform the Bachelier model taking an exponent and get the so-called Geometrical Brownian Motion or, equivalently, the Black-Scholes model. In the talk we investigate the classical Bachelier model using the theory of stochastic differential equations with reflection and absorption. It turns out the model with reflection may admit arbitrage, and therefore can not be appropriate for stock price modelling. The model with absorption at zero leads to the modification of the Bachelier model which is more closed to the Black-Scholes model in comparison with the classical Bachelier one. Working in this framework, we derive option pricing formulas as well as hedging strategies. Moreover, we propose a model of Bachelier with stochastic volatility and derive approximate option prices bounds using the theory of controlled diffusion processes together with the method of small perturbations of partial differential equations. Our findings are illustrated by numerical examples.

Pricing weather derivatives under Lévy models

Pablo Olivares

Ryerson University, Canada

Abstract: We price temperature and precipitation contracts under mean-reverting and switching Lévy models. An approximated closed-form pricing formula is obtained by using Fourier expansions of the characteristic function as in Oosterlee and Fang (2013). We compare the price obtained with a computationally costly but accurate Monte Carlo approach and study sensitivities with respect to relevant parameters, e.g. maturity, strike price and initial price. As the equivalent martingale measure(EMM) to create a risk-neutral setting we use the Esscher transformation. The technique is implemented in temperatures and precipitation data in Toronto and South Florida regions.

New trends in quantitative investing: ESG and artificial intelligence

Luis Seco

University of Toronto, Canada

Abstract: Portfolio optimization has been, for decades, built on objective functions based on risk and return. Today, investment trends are bringing into considerations other elements, such as impact investing, the environment and, in general, elements of social science which require a different approach to portfolio construction. In this talk, I will present the new investment realities and discuss new methodologies that employ artificial intelligence.

Cost-sensitive Multi-class AdaBoost for Understanding Driving Behavior with Telematics

Emiliano Valdez

University of Connecticut, USA

Abstract: Powered with telematics technology, insurers can now capture a wide range of data, such as distance traveled, how drivers brake, accelerate or make turns, and travel frequency each day of the week, to better decode driver's behavior. Such additional information helps insurers improve risk assessments for usage-based insurance (UBI), an increasingly popular industry innovation. In this article, we explore how to integrate telematics information to better predict claims frequency. For motor insurance during a policy year, we typically observe a large proportion of drivers with zero claims, a less proportion with exactly one claim, and far lesser with two or more claims. We introduce the use of a cost-sensitive multi-class adaptive boosting (AdaBoost) algorithm, which we call SAMME.C2, to handle such imbalances. To calibrate SAMME.C2 algorithm, we use empirical data collected from a telematics program in Canada and we find improved assessment of driving behavior with telematics relative to traditional risk variables. We demonstrate the competitiveness of our algorithm against other models that can handle class imbalances. The sampled data on telematics were observations during 2013-2016 for which 50,301 are used for training and another 21,574 for testing. Broadly speaking, the additional information derived from vehicle telematics helps refine risk classification of drivers of UBI. This is joint work with Banghee So and Jean-Philippe Boucher.

Polynomial affine approach to HARA utility maximization with applications
to Ornstein–Uhlenbeck 4/2 models

Yichen Zhu

Western University, Canada

Abstract: This paper designs a numerical methodology, named PAMH, to approximate an investor's optimal portfolio strategy in the contexts of expected utility theory (EUT) and mean-variance theory (MVT). Thanks to the use of hyperbolic absolute risk aversion utilities (HARA), the approach produces optimal solutions for decreasing relative risk aversion (DRRA) investors, as well as for increasing relative risk aversion (IRRA) agents. The accuracy and efficiency of the approximation is examined in a comparison to known closed-form solutions for a one dimensional (n=1) geometric Brownian motion with a CIR stochastic volatility model (i.e. GBM 1/2 or Heston model), and a high dimensional (up to n=35) stochastic covariance model.

Given the potential of this method, we investigate a relevant practical setting with no closed-form solution, namely when assets follow an Ornstein–Uhlenbeck 4/2 stochastic volatility (SV, i.e. OU 4/2) model. We conduct sensitivity analyses of the optimal strategies for DRRA and IRRA investors with respect to key parameters; (e.g. risk aversion, minimum capital guarantee and 4/2's parameters). In particular, the efficient frontier for the IRRA case is presented. A comparison to important sub-optimal strategies in terms of certainty equivalent rate (CER) is performed, indicating low CER performances due to ignorance of stochastic volatility for DRRA investors, i.e. a myopic strategy would be even better than ignoring SV. The analyses highlight the importance of efficient and precise numerical methods to obtain substantially higher CERs.
