

Winter Workshop on Operations Research, Finance and Mathematics, 2024

February 29 – March 4



Invited Speakers:

Konstantin Borovkov, Sebastian Jaimungal, Juri Hinz,
Yuri Kabanov, Nino Kordzakhia, Yue Kuen Kwok, Vincent Liang,
Alexander Novikov, and Mikhail Zhitlukhin.

Committee: Yukio Muromachi, Katsumasa Nishide, Takashi Shibata, Kohta Takehara, Tomonori Uchiyama, Kyoko Yagi, Toshinao Yoshiba, Tomooki Yuasa,

Local Organizer: Teruyoshi Suzuki

Venue: Asarigawaonsen Hotel, Otaru city, Hokkaido, Japan

Registration Fee: JPY 30,000

Organized by:

Research Center for Quantitative Finance, Tokyo Metropolitan University
The Operations Research Society of Japan, Hokkaido Branch

Schedule

All sessions are held in the 3rd floor conference room.

Feb. 29 (Thu)

Lecture

9:00 - 12:00 Ryo Miyata (Canceled)

Workshop

Chair: Youri Kabanov

14:00-15:00 Alexander Novikov, On parameter estimation diffusion processes: revisiting the sequential and fixed sample time approaches.

15:00-16:00 Masaaki Fukasawa, Backward stochastic difference equations on lattices with application to market equilibrium analysis.

Break

Chair: Takanori Adachi

16:15-17:15 Vincent Liang, On boundary crossing probabilities of diffusion processes.

17:15-18:15 Makoto Shimoshimizu, Trade execution games in a Markovian environment

Mar. 1 (Fri)

Lecture

9:00 - 12:00 Ryo Miyata (Canceled)

Workshop

Chair: Sebastian Jaimungal

14:00-15:00 Katsumasa Nishide, Competition in Liquidity Provision:
Analysis of High-Frequency Market-Making and Policy Implications

15:00-16:00 Toshinao Yoshiba, Tail dependence of copulas for financial risk
factors

Break

Chair: Vincent Liang

16:15-17:15 Nino Kordzakhia, On Maximal Inequalities and their
Applications.

17:15-18:15 Takanori Adachi, Hierarchical Structure of Uncertainty.

Mar. 2 (Sat)

Lecture (Japanese Language)

9:00 - 12:00 Katsumasa Nishide 「債券投資分析」

Workshop

Chair: Alexander Novikov

14:00-15:00 Kakeru Ito, The dynamics of tail dependence structure among multi-asset classes and its significance for portfolio management.

15:00-16:00 Konstantin Borovkov, Large deviation probabilities for random walks: Light vs heavy tails.

Break

Chair: Yue Kuen Kwok

16:15-17:15 Tomooki Yuasa, Second order unbiased simulation methods for Bally-Kohatsu's backward type and Henry-Tan-Touzi type.

17:15-18:15 Juri Hinz, Modelling Interest Rates with Forward Market Models.

Mar. 3 (Sun)

Local Workshop (Japanese Language)

Chair: 八木恭子

8:40 - 9:10 石井一成 「地域銀行の気候変動リスクに関する分析」

9:10 - 9:40 中村伊知雄 「預金取扱金融機関における債務者区分にかかる格付遷移行列の一因子表現を用いたフォーワードルッキングな一般貸倒引当金の算出」

9:40 - 10:10 兼子晃寛 「スパースグリッドを用いた後退確率微分方程式のマルチレベル空間離散化手法」

Break

Chair: 湯浅智意

10:30 - 11:00 山崎太裕 「Hawkes 過程に従う取引事象における Market Maker のモデルリスク評価」

11:00 - 11:30 西崎薫 「コモディティ市場におけるファクターの特徴とファクター間の関係性」

11:30 - 12:00 姫野公佐 「投資信託の資金フローに関わる要因分析」

Workshop

Chair: Juri Hinz

14:00-15:00 Yuri Kabanov, Optimal pair trading: consumption-investment problem.

15:00-16:00 Chiaki Hara, An Arrow-Pratt-Type Measure of Ambiguity Aversion.

Break

Chair: Mikhail Zhitlukhin

16:15-17:15 Takashi Shibata, Does debt-equity financing accelerate investments faster than all-equity financing? A real options framework.

17:15-18:15 Yue Kuen Kwok, Analytic solvability and efficient numerical schemes for pricing exotic derivatives under general stochastic volatility models.

Mar. 4 (Mon)

Lecture (Japanese Language)

9:00 - 12:00 Katsumasa Nishide 「債券投資分析」

Workshop

Chair: Nino Kordzakhia

14:00-15:00 Kohta Takehara, Analysis on Structure of Decentralized Exchanges.

15:00-16:00 Mikhail Zhitlukhin, Convergence of forecasts in prediction markets.

Break

Chair: Konstantin Borovkov

16:15-17:15 Ryoji Takano, A partial rough path space for rough volatility

17:15-18:15 Sebastian Jaimungal, Minimal Kullback-Leibler Divergence for Constrained Levy-Ito Processes and Applications.

18:15 Closing address by Tomonori Uchiyama, Director of Research Center for Quantitative Finance, Tokyo Metropolitan University, Japan

Feb. 29 (1)

On parameter estimation diffusion processes: revisiting the sequential and fixed sample time approaches

Alexander Novikov

University of Technology, Sydney (UTS), Australia

In this talk, we will revisit some results from the monograph "Statistics of Random Processes, Vol. II, Springer, 2001" by R.Liptser and A.Shiryaev concerning estimation and testing of parameters of a drift function. We will present general formulae for moments of the sequential maximum likelihood estimators (MLE) of the parameters. Then we will consider a class of mean-reverting ergodic diffusion process $X = \{X_t, 0 \leq s \leq \tau\}$ with a volatility of the form $\sigma X_t^\gamma, \gamma \geq 0$, and a drift $\lambda(\theta - X_t)$, where τ is any stopping time. In particular, we will present the analytical results for exact values of the bias and mean-squared-error of MLE λ_T when $T = \text{const}$ (i.e. a fixed sample size). We also consider the sequential estimator λ_{τ_H} with the stopping time τ_H that guarantees the predefined variance of $(1/H)$. For comparative analysis, we will also provide some analytical and numerical results.

This presentation is based on joint papers with Dr. Nino Kordzakhia (Macquarie University, Sydney) and Albert Shiryaev (Steklov Mathematical Institute).

Feb. 29 (2)

Backward stochastic difference equations on lattices with application to market equilibrium analysis

Masaaki Fukasawa

Osaka University, Japan

We study backward stochastic difference equations (BS Δ E) driven by a d -dimensional stochastic process on a lattice whose increments have only $d + 1$ possible values that generates the lattice. Regarding the driving process as a d dimensional asset price process, we give applications to an optimal investment problem and a market equilibrium analysis, where utility functionals are defined through BS Δ E. A joint with Takashi Sato and Jun Sekine.

Feb. 29 (3)

On boundary crossing probabilities of diffusion processes

Vincent Liang

The University of Melbourne, Australia

We discuss two results related to the probability $F(g_-, g_+)$ that a general time-inhomogeneous diffusion process X stays between two curvilinear boundaries g_- and g_+ (possibly with $g_{\pm} = \pm\infty$) during a finite time interval.

First we discuss a discrete time discrete space Markov chain approximation to X with a Brownian bridge correction for computing $F(g_-, g_+)$. For a broad class of g_{\pm} and diffusion processes, we prove the convergence of the constructed approximations to $F(g_-, g_+)$ in the form of products of the respective substochastic matrices as the time grid is getting finer. Numerical results indicate that the convergence rate is $O(n^{-2})$ in the case of C^2 -boundaries and a uniform time grid with n steps.

In the second part of the talk, in the case when $g \in C^2$, we prove the existence of and obtain an explicit compact representation for the Gâteaux derivative $\nabla_h F(-\infty, g)$ of the boundary non-crossing probability functional in the direction $h \in H \cup C^2$.

Joint work with K. Borovkov.

Feb. 29 (4)

Trade execution games in a Markovian environment

Makoto Shimoshimizu

Tokyo University of Science, Japan

This paper examines a trade execution game model in a Markovian environment. We focus on how two risk-averse large traders execute a large volume of a risky asset to maximize each large trader's expected utility from the terminal wealth over a finite horizon. The price impact caused by the large traders and what we call the Markovian environment are assumed to affect the market price and execution price. Formulation as a Markov game model enables us to solve this problem. We obtain an execution strategy and its associated value function under a Markov perfect equilibrium via the backward induction method of dynamic programming. Comparative statics with simulation-based analysis reveals that the execution strategy at the Markov perfect equilibrium can capture the feature observed in financial markets.

Mar. 1 (1)

Competition in Liquidity Provision: Analysis of High-Frequency Market-Making and Policy Implications

Katsumasa Nishide

Hitotsubashi University, Japan

We construct a financial market model wherein market makers post limit orders to compete for liquidity provision. We show that market makers may relinquish liquidity provision because of competition if the fundamental value of the asset is volatile. Besides the general perception that cancellation harms market liquidity, we find that cancellation can sustain liquidity and prevent depletion. Moreover, this finding, as well as others, leads to an important policy implication that the cancellation strategy, one of the most prominent characteristics of high-frequency trading, can positively affect market liquidity and should not be strictly regulated. (Joint work with Takaki Hayashi)

Mar. 1 (2)

Tail dependence of copulas for financial risk factors

Toshinao Yoshiba

Tokyo Metropolitan University, Japan

Tail dependence of risk factors matters in financial portfolio risk management. The normal (Gaussian) copula was widely used to evaluate the value of collateralized debt obligation before the global financial crisis in 2009. The method was criticized as the normal copula cannot well capture the joint loss of underlying assets in stress due to the asymptotic independence. Against the background, the Student-t copula with more tail dependence than the normal copula is sometimes utilized in practice for financial risk factors. Furthermore, to capture stronger tail dependence of the lower side of risk factors than that of the upper side, some recent studies incorporate the skewness in the normal or the Student-t copulas. In this talk, we focus on the tail dependence of the normal, Student-t, skew-normal, skew-t copulas. We theoretically summarize the recent studies (Yoshiba, 2018; Yoshiba, Koike, and Kato, 2023) for the tail dependence of the bivariate copulas with introducing the notion of the tail order.

Mar. 1 (3)

On Maximal Inequalities and their Applications.

Nino Kordzakhia

Macquarie University, Australia

We will overview the extensions of the Kolmogorov inequality for the distribution of the absolute value of the maximum of the sum of centered independent random variables to the case of martingales at random stopping times. We will discuss the new results related to the exponential inequalities for maximum of a generalised Ornstein-Uhlenbeck process (gO-U) under some assumptions on tail distributions of a jump component. A survey of the applications of the maximal inequalities will be also provided.

Mar. 1 (4)

Hierarchical Structure of Uncertainty

Takanori Adachi

Tokyo Metropolitan University, Japan

We express n-layer uncertainty, which we call hierarchical uncertainty by introducing a new concept called uncertainty spaces that is an extended concept of probability spaces and U-sequence that is a hierarchically constructed sequence of uncertainty spaces. We use U-sequences for providing examples that illustrate Ellsberg's paradox. Then, we analyze the structures with tools in category theory.

Mar. 2 (1)

The dynamics of tail dependence structure among multi-asset classes and its significance for portfolio management

Kakeru Ito

Nissay Asset Management, Japan

In this study, we propose AC dynamic skew-t copula with cDCC model to capture dynamic asymmetric tail dependence structure among multi-asset classes (government bonds, corporate bonds, equities, and REITs). The empirical analysis shows that our proposed dynamic AC skew-t copula fits data of multi-asset classes better than other dynamic elliptical copulas including conventional dynamic skew-t copula in terms of AIC and BIC. Besides, lower tail dependence coefficients have recently increased compared to upper tail dependence coefficients for all pairs. It indicates that the diversification effect through multi-asset investment has been decreasing, and investors should enhance tail risk management. Furthermore, out-of-sample analysis shows that using dynamic skew-t copula, especially our proposed model, enhances expected shortfall (ES) estimation accuracy and the performance of minimum ES portfolio compared to dynamic t copula and dynamic normal copula. It indicates that capturing dynamic asymmetric tail dependence is crucial for multi-asset investment. Joint work with Toshinao Yoshihara.

Mar. 2 (2)

Large deviation probabilities for random walks: Light vs heavy tails

Konstantin Borovkov

The University of Melbourne, Australia

Random walks are important models for real-life processes, including claim surplus processes for insurance companies, where light-tailed jump distributions are usually assumed for life insurance, and heavy-tailed – for non-life one. We will present the fundamentals of the large deviations theory for random walks, touching on both light- and heavy-tailed cases, and outline results on the asymptotics of the probabilities of remote curvilinear boundary crossing by the walks. We will also discuss large deviation results in the case of right-censored jumps in the random walk. [Part of the work was joint with A. Chong.]

Mar. 2 (3)

Second order unbiased simulation methods for
Bally-Kohatsu's backward type
and Henry-Tan-Touzi type

Tomooki Yuasa

Tokyo Metropolitan University, Japan

Wagner (1989), Bally-Kohatsu (2015), and Henry-Tan-Touzi (2017) developed unbiased simulation methods, which are stochastic numerical methods for functionals of solutions of stochastic differential equations. The unbiased simulation method is characterized by the absence of weak errors and fast computation time. However, the variance is not necessarily finite. Therefore, Anderson-Kohatsu-Yuasa (2020) developed a second-order unbiased simulation method in which all moments, including the variance, are finite. They achieved this by applying Romberg's method to the order of an infinite series expansion of the functional. Their paper discusses in particular Bally-Kohatsu's forward type unbiased simulation method. In this presentation, I will introduce second order unbiased simulation methods for Bally-Kohatsu's backward type and Henry-Tan-Touzi type.

Mar. 2 (4)

Modelling Interest Rates with Forward Market Models

Juri Hinz

National Australia Bank, Australia

The modern practice in financial industry is based on interest rate models which incorporate both, the spitting of the discount curve and the mechanisms to deal with the cessation of LIBOR rates. As a result, practitioners face a technically challenging situation, which requires dealing with several discount curves at once, while handling diverse fall-back rules for appropriate LIBOR proxies. In this framework, pricing models are usually high-dimensional and even simplest instruments are easily becoming highly path-dependent. This talk reflects an insider's view of the so-called Forward Market Model (FMM) – a state-of-the-art approach which is designed to support all useful LIBOR methodologies in the post-LIBOR multi-curve era.

Mar. 3 (1)

Optimal pair trading: consumption-investment problem

Youri Kabanov

Lomonosov Moscow state university and the "Vega" Institute, Moscow,
Russia

The pair trading is based on the idea that stocks of companies having similar business are strongly correlated and their difference fluctuates near zero. A trader matches a long position with a short position in two stocks having a high correlation. The portfolio value increment is proportional to the increment of the spread between prices. By this reason such a setting, frequently used by hedge funds, is also called spread trading. The spread trading is intensively used by hedge funds and the literature on it is enormous. In this talk we present a complete solution of the problem on a finite time interval in the setting similar to that of the famous Merton problem. This solution is much simpler than available in the literature and merits to be included in the advanced lecture courses on stochastic control. The talk is based on a joint note with Alexei Kozhevnikov.

Mar. 3 (2)

An Arrow-Pratt-Type Measure of Ambiguity Aversion

Chiaki Hara

Kyoto University, Japan

We define a measure of ambiguity aversion for ambiguity-averse utility functions in a way analogous to the Arrow-Pratt measure of risk aversion. The measure is determined by the second Peano derivative, which exists even for non-differentiable functions, such as maximin and Choquet expected utility functions. Unlike the standard notion of comparative ambiguity aversion, it allows us to compare ambiguity aversion between two utility functions exhibiting different risk attitudes. We introduce a notion of ambiguity premium and show that our measure is related to the second-order, as opposed to the first-order, ambiguity premium. We also show that it is related to the first-order impact on matching probabilities of the size of prizes.

Mar. 3 (3)

Does debt-equity financing accelerate investments faster than all-equity financing? A real options framework

Takashi Shibata

Tokyo Metropolitan University, Japan

This study examines whether debt-equity financing accelerates investments faster than all-equity financing. This is the case in non-competitive markets (i.e., monopolies) because the firm obtains full leverage effects. We use the approach taken by Dixit and Pindyck (1994, Section 8.2) to describe the competitive market structure and show that the claim does not necessarily hold in competitive markets. In particular, debt-equity financing delays investments more than all-equity financing when market competitiveness is high. Investments by debt-equity-financed firm are delayed owing to two mechanisms. First, market competition forces debt-equity-financed firms to reduce their leverage effects, which is consistent with the results of past empirical studies. Second, investments are more elastic than financing when we consider interactions because the firm does not want to reduce the leverage effect.

Mar. 3 (4)

Analytic solvability and efficient numerical schemes
for pricing exotic derivatives
under general stochastic volatility models

Yue Kuen Kwok

FinTech Thrust, Hong Kong University of Science and Technology,
Guangzhou, China

A thorough investigation on analytic solvability of general stochastic volatility models with jumps is presented. By an effective measure change technique, we develop an effective analytic approach of deriving the conditional moment generating functions that are essential for developing efficient numerical schemes for pricing derivatives under a wide variety of stochastic volatility models. Computational efficiency is much enhanced to the extent that numerical pricing of discrete exotic variance derivatives only requires a few dozen CPU seconds with numerical accuracy up to 3 to 4 significant figures. The bottleneck of the time-consuming Fourier inversion in traditional exact simulation schemes is resolved.

Mar. 4 (1)

Analysis on Structure of Decentralized Exchanges

Kohta Takehara

Tokyo Metropolitan University, Japan

Decentralized exchanges are a key concept in DeFi. They often employ automated market makers, which are algorithms that pool liquidity and make it available to users of the DEX at automatically determined prices. This study categorizes DEX players into Platformers, Liquidity Providers, Arbitrageurs, and Traders, and analyzes how the structure of DEXs is affected by the actions and optimizations of these players. Some numerical examples intuitively illustrate the trade-offs between the players.

Mar. 4 (2)

Convergence of forecasts in prediction markets

Mikhail Zhitlukhin

Steklov Mathematical Institute, Russia

Prediction markets are artificial markets designed for aggregating information scattered among traders. We construct a dynamic model of a prediction market and study conditions for convergence of aggregated forecasts to true conditional expectations. The main results are based on martingale convergence theorems.

Mar. 4 (3)

A partial rough path space for rough volatility

Ryoji Takano

Osaka University, Japan

We develop a variant of rough path theory tailor-made for analyzing a class of financial asset price models known as rough volatility models. As an application, we prove a pathwise large deviation principle (LDP) for a certain class of rough volatility models, which in turn describes the limiting behavior of implied volatility for short maturity under those models. This presentation is based on a joint work with Professor Masaaki Fukasawa.

Mar. 4 (4)

Minimal Kullback-Leibler Divergence for Constrained Levy-Ito Processes and Applications

Sebastian Jaimungal

University of Toronto, Canada

In many settings, a modeler may have trained a model on data but that trained model is not consistent with their beliefs - e.g., the average time the process spends below some barrier is 10% from the estimated model, but their belief about the future evolution is that it should be 20%. Hence, they would like to modify this model in a minimal manner that respects their beliefs. Here we study such questions. More generally, given an n -dimensional stochastic process X driven by P -Brownian motions and Poisson random measures, we seek the probability measure Q , with minimal relative entropy to P , such that the Q -expectations of some terminal and running costs are constrained. We prove the existence and uniqueness of the optimal probability measure, derive the explicit form of the measure change, and characterise the optimal drift and compensator adjustments under the optimal measure. This talk will provide a high level view of how we solve this problem and several examples stemming from finance and insurance.

Mar. 3, Local Workshop (1)

地域銀行の気候変動リスクに関する分析

石井 一成

東京都立大学大学院 経営学研究科

本研究では、Jung/Engle/Berner [2023]が提案する気候変動リスク指標CRISKを用いて、日本の地域銀行の気候変動リスクを推定し、地域銀行のTCFD開示と融資ポートフォリオの産業構成が気候変動リスクに与える影響を分析した。その結果、気候リスクファクターに対する株価リターンの感応度である気候ベータとCRISKが2017年から2022年にかけて増加傾向にあり、気候変動リスクに関する情報開示や融資ポートフォリオの産業構成におけるブラウン産業の割合の高まりが、地域銀行の気候ベータまたはCRISKを高めることがわかった。

Mar. 3, Local Workshop (2)

預金取扱金融機関における債務者区分にかかる 格付遷移行列の一因子表現を用いた フォーワードルッキングな一般貸倒引当金の算出

中村 伊知雄

東京都立大学大学院 経営学研究科

預金取扱金融機関の正常先債権と要注意先債権にかかる一般貸倒引当金については、過去の貸倒実績率等をベースとした手法で見積もる実務慣行が定着してきた。近年、世界的に発生損失型引当金から予想損失型引当金（IFARS9、CECL）への移行が進んでいることなどを背景に、本邦でも「過去の貸倒実績率等に限らず、将来予測情報等、幅広い情報から信用リスクを認識する」フォーワードルッキング型の引当金の導入が進みつつある。しかしながら、こうしたフォーワードルッキング型の引当金に関する具体的な算出は、人員制約のある地域金融機関では自力でのモデル構築に困難を伴うほか、都道府県単位の統計情報等は限られるなど、データ面での制約も大きい。そこで本研究では、このような制約を意識し、正確性と実務上の扱いやすさのバランスを考慮した一般貸倒引当金の算出方法として、債務者区分にかかる格付遷移行列の一因子表現を用いた手法について、実際の地方銀行での事例を取り上げて提示する。

Mar. 3, Local Workshop (3)

スパースグリッドを用いた後退確率微分方程式の マルチレベル空間離散化手法

兼子晃寛

大阪大学大学院 基礎工学研究科

ブラウン運動 (BM) で駆動される高次元後退確率微分方程式 (BSDE) を空間離散化し、連続時間有限状態マルコフ連鎖 (CTMC) で駆動される BSDE を導出することを考える。標準的な格子上での離散化の場合、CTMC の状態数が元の BM-BSDE の空間次元に対し指数関数的に増大し、数値計算においては「次元の呪い」が発生する。本研究では、様々な解像度の格子上に配置された複数の CTMC-BSDE の解を組み合わせ、BM-BSDE の解を効率的かつ精度高く近似する、スパースグリッド法に基づいたマルチレベル離散化法を提案する。

Mar. 3, Local Workshop (4)

Hawkes 過程に従う取引事象における Market Maker のモデルリスク評価

山崎太裕

東京都立大学大学院 経営学研究科

本研究では、市場で指値注文を繰り返し発注する Market Maker を分析対象とする。Avellaneda and Stoikov (2008) では市場の注文発生が Poisson 過程に従うと想定し、最適 spread の近似式を導出している。一方、田代・川口 (2017) では市場の注文発生は Poisson 過程を一般化した Hawkes 過程を用いることでより精緻に表現できる特徴を持つことが指摘されている。本研究では、市場の注文発生が Poisson 過程に従うと想定し、Avellaneda and Stoikov (2008) による spread を用いる Market Maker のもつモデルリスクを評価したい。このため、本邦株式データより Hawkes 過程のパラメータを推定した上で、Market Maker が Poisson 過程を前提に算出した資産額・手元流動性・在庫量に関するリスク量と、推定された Hawkes 過程を前提に再計算されたリスク量の差をモデルリスクとして捉え、比較・分析をおこなう。

Mar. 3, Local Workshop (5)

コモディティ市場におけるファクターの特徴とファクター間の関係性

西崎薫

東京都立大学大学院 経営学研究科

コモディティ市場におけるファクターに焦点を当て、その特徴やファクター間の関係を明らかにする。リターンをキャピタルゲインとイールドの2種類に分解して分析を行い、ファクターにおける新たな特徴や関係性を発見する。また、株式ファクターとの関係やボラテリティとの関係についても分析を行う。

Mar. 3, Local Workshop (6)

投資信託の資金フローに関わる要因分析

姫野公佐

東京都立大学大学院 経営学研究科

投資信託の資金フローの要因を、過去のパフォーマンスが将来の資金フローに影響を与えるとする情報シグナル仮説と、ディスポジション効果や宝くじ選好、ナンピン買いが関係しているとする行動バイアス仮説の2つの観点から実証分析を行った。その結果、投資家は過去のファクター考慮後のリターンが高いファンドに相対的に多くの資金を投じていることが明らかになったことに加え、資金フローにはナンピン買いによる影響も含まれていることと整合的な結果が得られた。