IP1

Algorithmic and High-Frequency Trading

This talk will provide an overview of the state-of-the-art of algorithmic and high-frequency trading with an emphasis on stochastic control techniques. We will look at trading problems involving mean field games (arising when multiple agents are optimizing against one another), robust stochastic control (to account for model uncertainty), and partial information (when unobserved states modulate the system). The talk will highlight the interesting mathematical problems that arise and the financial intuition behind the results. [Various joint works with lvaro Cartea, Philippe Casgrain, Ryan Donnelly, Bill Huang, and Mojtaba Nourin]

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IP2

Bubbles in Assets with Finite Life

We treat the speculative value of a finitely-lived asset when investors disagree and short sales are limited. When acquiring the asset, investors are willing to pay a speculative value for the resale option. Using martingale arguments, we characterize the equilibrium speculative value as a solution to a fixed-point problem for a monotone operator. A Dynamic Programming Principle is used to show that the minimal solution to this problem is a viscosity solution of a (non-local) obstacle problem. This obstacle problem satisfies a comparison principle. Combining the monotonicity of the operator and the comparison principle we obtain several comparison of solution results. Underlying papers were coauthored with H. Berestycki, C. Bruggeman and R. Monneau.

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IP3

Stochastic Calculus in Weak Formulation, with Applications

While it is widely used in economics literature, the weak formulation has received less attention than the standard strong formulation in stochastic community. In this talk, we will first motivate the weak formulation by several examples from economics/finance as well as stochastic controls/games. We then discuss nonlinear expectation and path dependent PDEs, which are by nature built upon weak formulation.

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IP4

A Principal-Agent Model for Pricing Electricity Demand Volatility

The development of renewable energy sources for electricity generation in the electric systems are renewed the interest for demand response programs. Indeed, the volatility of renewable energies compels systems operator and electric utilities to increase their storage capacity to be able to cope with these important variations over small time steps. Instead of using a physical storage solution, we propose a model of demand pricing that allow a producer to incite a consumer to smooth her consumption over time. We use a Principal-Agent framework where the agents consumption volatility is controlled, find the optimal contract and show with numerical illustrations how the agents consumption volatility is reduced.

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IP5

Causal Optimal Transport and its Links to Enlargement of Filtrations and Stochastic Optimization Problems

The martingale part in the semimartingale decomposition of a Brownian motion, with respect to an enlarged filtration, is an anticipative mapping of said Brownian motion. In analogy to optimal transport theory, I will define causal transport plans in the context of enlargement of filtrations, as the Kantorovich counterparts of the aforementioned non-adapted mappings. I will present a necessary and sufficient condition for a Brownian motion to remain a semimartingale in an enlarged filtration, in terms of certain minimization problems over sets of causal transport plans. The latter will be also used in order to give an estimate of the value of having additional information, for some classical stochastic optimization problems. This talk is based on a joint work with Julio Backhoff and Anastasiia Zalashko.

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IP6

Mathematical Models for Financial Asset Price Bubbles

In this talk we present some recent results concerning the mathematical modelization of financial asset bubbles. We study a flow in the space of equivalent martingale measures and the corresponding shifting perception of the fundamental value of a given asset. We then extend the concept of financial bubble in a market model endowed with a set of probability measures, typically mutually singular to each other. We conclude by considering a mathematical model for the birth and evolution of bubbles in a network of investors.

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IP7

Systems of Backward Stochastic Differential Equations and Applications in Finance and Game Theory

Systems of nonlinear backward stochastic differential equations (BSDEs) appear throughout mathematical finance, optimal stochastic control and stochastic game theory. For example, the important question of existence and uniqueness of incomplete-market financial equilibria can be rephrased as a system of BSDEs under appropriate conditions. Unlike in the case of a single equation, where tight

necessary and sufficient conditions for existence an uniqueness are known, only partial results are available for systems. Recently, Hao Xing and myself established existence and uniqueness for a wide class of Markovian systems of BSDEs with quadratic nonlinearities. This class is characterized by an abstract structural assumption on the generator, an a priori local-boundedness property, and a locally-Hlder-continuous terminal condition. Easily verifiable sufficient conditions for these assumptions are available and they apply to several systems found in applications, including the aforementioned stochastic equilibria in incomplete financial markets, stochastic differential games, as well as those related to construction of martingales on Riemannian manifolds. Joint work with Hao Xing (London School of Economics).

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IP8

EM Algorithm and Stochastic Control

We propose an algorithm called EM-Control (EM-C) algorithm to solve multi-period finite-time horizon stochastic control problems, where the optimal policy is not necessarily stationary. Generalizing the idea of the EM algorithm, the EM-C algorithm sequentially updates the control parameters in each time period in a time-backward manner. Similar to the EM algorithm, the EM-C algorithm has monotonicity of performance improvement in every iteration, and hence has good convergence properties. We apply the EM-C algorithm to solve stochastic control problems in real business cycle and monopoly pricing of airline tickets, showing the effectiveness of the algorithm. This is a joint work with Xianhua Peng and Xingbo Xu.

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CP1

Heterogeneous Risk Preferences in Financial Markets

This paper builds a continuous time model of N heterogeneous agents whose CRRA preferences differ in their level of risk aversion and considers the Mean Field Game (MFG) in the limit as N becomes large. The model represents a natural extension of other work on heterogeneous risk preferences (e.g. Cvitanic, et. al., (2011) "Financial Markets Equilibrium with Heterogeneous Agents". Review of Finance, 16, 285-321) to a continuum of types. I add to the previous literature by characterizing the limit in N and by studying the short run dynamics of the distribution of asset holdings. I find that agents dynamically self select into one of three groups depending on their preferences: leveraged investors, diversified investors, and saving divestors, driven by a wedge between the market price of risk and the risk free rate. The solution is characterized by dependence on individual holdings of the risky asset, which in the limit converge to a stochastic flow of measures. In this way, the mean field is not dependent on the state, but on the control, making the model unique in the literature on MFG and providing a convenient approach for simulation. I simulate both the finite types and continuous types economies and find that both models match qualitative features of real world financial markets. However, the continuous types economy is more robust to the definition of the support of the distribution of preferences and computationally less costly than the finite types economy.

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CP1

Network Sensitivity and Risk in Sharing Economies

Sharing economies such as Uber and Airbnb have grown enormously in popularity over the last decade, due in large part to the ease of access on the part of the consumer. The connections between possible customers and desired resources (cars, home rentals, etc.) allow us to define the business model as an undirected graph with customers establishing links to products and services. The topology of this network is of great interest as certain network characteristics entail financial risk to firm, and the recognition of such risks is not necessarily straightforward. These networks are sensitive to the extent that even small changes relative to the network as a whole can result in the destruction of the entire system. We approach the problem in three directions. We first show that these networks exhibit scale-free properties, which imply sensitivity to a small number of nodes. We then compute the connection likelihood functions that define how the network grows or shrinks, which differ for each application and impact the likelihood of utilization. Finally, we examine the sensitivity of the network to changes in the connection likelihood functions. We examine this concept in two ways, first by computing connection likelihood domains and second, examining the impact if the likelihood of connection falls below a critical value and how long the network can remain operational. We also propose a measure of resilience that can be broadly applied to sharing economies.

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CP1

Sensitivity Analysis of the Eisenberg-Noe Network Model

The financial system is increasingly interconnected. Cyclical interdependences among corporations may cause that the default of one firm seriously affects other firms and even the whole financial network. To describe financial networks, L. Eisenberg and T. Noe introduced network models that became popular among researchers and practitioners. To describe the connections between firms, they use the liabilities between two firms to construct relative liability matrices. Based on this description, they compute the payouts of firms to their counterparties. However, in practice, there is no accurate record of the liabilities and researchers have to resort to estimation processes. Thus it is very important to understand possible errors of payouts due to the estimation errors. In our research, we describe estimation errors via sizes and directions of perturbations in the relative liability matrices. We quantify the effect of estimation errors to payouts using directional directives and derive the formula $D_B(p(A)) = (I - \Lambda A^T)^{-1}\Lambda B^T p(A)$ in the regular financial network. To understand the effect of estimation errors to the society payout, we introduce a generalization

of the model, capturing obligations of financial institutions to the society as a whole. For a given estimation error size, we compute the effect to the society payout along the worst estimation error.

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CP1

Systemc Risk and Interbank Lending

We propose a simple model of inter-bank lending and borrowing incorporating a game feature where the evolution of monetary reserve is described by a system of coupled Feller diffusions. The optimization subject to the quadratic cost not only reflects the desire of each bank to borrow from or lend to a central bank through manipulating its lending preference but also to intend to leave deposits in a central bank in order to control the volatility for cost minimization. We observe that the adding liquidity creates the effect of flocking leading to stability or systemic risk according to the level of the growth rate. The deposit rate brings about a large number of bank defaults by diminishing the growth of the system. A central bank acts as a central deposit corporation. In addition, the corresponding Mean Field Game in the case of the number of banks N large and the stochastic game on the infinite horizon with the discount factor are also discussed. Finally, we solve for the closed-loop equilibria in the case of inter-bank lending and borrowing with clearing debt obligations using the stochastic game with delay.

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CP2

Accelerating Xva Computations by Chebyshev Interpolation

The calculation of the various credit and funding adjustments to the price of derivatives, commonly known as XVAs, remains to be one of the most intensive ones in finance. At the netting set level, this typically involves a Monte Carlo simulation of the whole portfolio of derivatives facing a counterparty, which in turn requires evaluating individual pricers thousands of times. When they involve lengthy calculations (e.g., time-dependant derivatives priced with Monte Carlo simulation) this becomes a bottleneck difficult to overcome in the computation of XVA. In this talk we propose a method for constructing polynomial surrogates that can be evaluated efficiently and to high accuracy, instead of invoking directly the pricers. Supporting this method is the well-developed theory of Chebyshev interpolation and series, a central theme in classical approximation theory and one of the foundations of spectral methods for solving PDEs. In the realm of Uncertainty Quantification, the proposed method falls under the category of non-intrusive or sampling-based, that is, the method uses already existing pricers and in effect it boosts their speed. Numerical experiments of the method ran in the software package Chebfun will also be presented.

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CP2

Credit Value Adjustment Calculation with Wrong Way Risk

Credit value adjustment (CVA) is an adjustment added to the fair value of an over-the-counter trade due to the risk of counterparty defaults. When the exposure to the counterparty and the counterparty default risk change in the same direction, the so-called wrong-way risk (WWR) must be taken into account. The WWR amplifies the loss due to default and it brings more challenges to the CVA calculation. In this paper, we develop a new approach to calculate the CVA with WWR. In particular, we decompose the WWR into two factors, a robust correlation and a profile multiplier with further economic meanings. This approach is robust and it does not depend on distributions. In addition, we develop an efficient algorithm that can save the computational time dramatically. Using our approach, a confidence interval for CVA can be obtained if there is an uncertainty with the correlation structure.

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CP2

Rational Multi-Curve Models with Counterparty-Risk Valuation Adjustments

We develop a multi-curve term structure setup in which the modelling ingredients are expressed by rational functionals of Markov processes. We calibrate to LIBOR swaptions data and show that a rational two-factor lognormal multi-curve model is sufficient to match market data with accuracy. We elucidate the relationship between the models developed and calibrated under a risk-neutral measure Q and their consistent equivalence class under the real-world probability measure P. The consistent P-pricing models are applied to compute the risk exposures which may be required to comply with regulatory obligations. In order to compute counterparty-risk valuation adjustments, such as

CVA, we show how default intensity processes with rational form can be derived. We flesh out our study by applying the results to a basis swap contract.

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CP2

Pricing and Hedging Credit Derivatives with Dependent Structures

We study the problem of pricing and hedging credit derivatives with dependent structures and we are interested in CDSs in particular. For pricing, we consider the Gaussian Copula approach and apply it to 3 different models. For hedging, both delta hedge and delta-gamma hedge are taken into consideration, and the single-name CDSs are taken as the hedging instruments. Furthermore, hedging efficiency measure is also introduced for testing hedging results. Numerical experiments illustrate our hedging methods.

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CP3

Local Risk-Minimization for Barndorff-Nielsen and Shephard Models

We obtain explicit representations of locally risk-minimizing strategies of call and put options for the Barndorff-Nielsen and Shephard models, which are Ornstein–Uhlenbeck-type stochastic volatility models. Using Malliavin calculus for Lévy processes, Arai and Suzuki (2015) obtained a formula for locally risk-minimizing strategies for Lévy markets under many additional conditions. Supposing mild conditions, we make sure that the Barndorff-Nielsen and Shephard models satisfy all the conditions imposed in Arai and Suzuki. Among others, we investigate the Malliavin differentiability of the density of the minimal martingale measure. Moreover, some numerical experiments for locally risk-minimizing strategies are introduced.

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CP3

Utility-Based Valuation of Perpetual Income Streams

We develop a marginal utility-based valuation method for perpetual income streams, using a consumption-based version of Davis' (1997) marginal rate of substitution valuation method. One adds a random income stream to an infinite horizon utility of consumption problem, and requires that an infinitesimal diversion of initial wealth into the random endowment has no effect on achievable utility. The resulting valuation formula features marginal utility of optimal consumption as a *horizon-independent* pricing kernel. Examples using a classical utility are given, and contrasted with the use of a forward utility, in which horizon independence is automatically built into the valuation scheme by definition.

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CP3

Shortfall Aversion in a Finite Horizon

This paper considers a utility of spending scaled by the past peak spending, and solves an optimal spending-investment problem in a finite horizon. A closed form solution has been achieved. It suggests that the spending rate is constant and equals the historical peak for relatively large values of wealth/peak consumption, decreases when the ratio is relatively small, and in particular, increases when the ratio reaches an upper bound.

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CP3

Market Stability and Indifference Prices

Consider a derivative security whose underlying is not replicable yet is highly correlated with a traded asset. As the correlation between the underlying and traded asset increases to 1, do the claim's indifference prices converge to the arbitrage-free price? In this talk, I will first present a counterexample in a Brownian setting with a power utility investor where the indifference prices do not converge. The counterexample's degeneracies are alleviated for utility functions on the real line, and a positive convergence result will be presented in this case.

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CP4

Singular Control Approximation and Viscosity So-

lution Selection Principle in Optimal Investment and Consumption with Tax

We consider a singular stochastic control problem arising from continuous time investment and consumption with capital gains tax, where the associated Hamilton-Jacobi-Bellman (HJB) equation admits infinitely many solutions. In terms of an explicit construction, we show that the optimal strategy can be approximated by a sequence of sub-optimal strategies related to regular control. As far as we know, this is the first paper to explicitly construct such approximations in the singular control literature. Since the constructed sub-optimal strategies lead to a penalized approximation of the HJB equation, our result demonstrates that the penalty method can still work for numerical solutions, even if the HJB equation lacks uniqueness of solutions. We also show that the resulting value function corresponds to the minimal viscosity solution of the HJB equation. Our approach can be extended to general singular stochastic problems. This work is jointly with Baojun Bian and Xinfu Chen.

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CP4

Dynamic Portfolio Optimization Across Hidden Market Regimes

Regime-based asset allocation has been shown to add value over rebalancing to static weights and, in particular, reduce potential drawdowns by reacting to changes in market conditions. The predominant approach in previous studies has been to specify in advance a static decision rule for changing the allocation based on the state of financial markets or the economy. This talk proposes the use of model predictive control to dynamically optimize a portfolio based on forecasts of the mean and variance of financial returns from a hidden Markov model with time-varying parameters. There are computational advantages to using model predictive control when estimates of future returns are updated repeatedly, since the optimal control actions are reconsidered anyway every time a new observation becomes available. Results from testing the approach on market data are presented and compared with previous, rule-based approaches. Further, imposing a trading penalty that reduces the number of trades is discussed as a way to increase the robustness of the approach.

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CP4

Cumulative Prospect Theory with Skewed Return Distribution

We investigate a one-period portfolio optimization problem of a cumulative prospect theory (CPT) investor with multiple risky assets and one risk-free asset. The returns of multiple risky assets follow multivariate generalized hyperbolic (GH) skewed t distribution. We obtain a three-fund separation result of two risky portfolios and risk-free asset. Furthermore, we reduce the high dimensional optimization problem to two 1-dimensional optimization problems and derive the optimal portfolio. We show that the optimal portfolio composition changes as some of investor-specific parameters change. It is observed that the consideration of skewness of stock return distribution has considerable impact on the distribution of CPT investor's wealth deviation, and leads to less total risky investment.

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CP4

Consumption in Incomplete Markets

As intertemporal consumption with market incompleteness leads to intractable value functions even in simple models, this paper develops approximate solutions to the maximization of isoelastic utility from consumption with infinite horizon in an incomplete market where state variables follow a multivariate diffusion. After proving a general verification theorem that links the solution of the Hamilton-Jacobi-Bellman (HJB) equation to the value function and optimal consumption-investment policies, the paper develops pointwise upper and lower bounds of the value function, which have closed-form solutions in typical models and lead to approximate policies with an explicit bound on the certainty-equivalent loss. In general, these policies are optimal for a fictitious complete market in which the safe rate and state variables follow different dynamics, but excess returns are the same; if the market is complete or utility is logarithmic, they are optimal even for the original market. Further, the approximations correspond to sub- and super-solutions to the original HJB equation, and lead to the existence of a solution.

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CP5

A Probabilistic Max-Plus Numerical Method for Solving Stochastic Control Problems

We consider fully nonlinear Hamilton-Jacobi-Bellman equations associated to diffusion control problems involving a finite set-valued (or switching) control and possibly a continuum valued control. We construct a lower complexity probabilistic numerical algorithm by combining the idempotent expansion properties obtained by McEneaney, Kaise and Han (2011) for solving such problems with a numerical probabilistic method such as the one proposed by

Fahim, Touzi and Warin (2011). There are very restrictive conditions for this latter method to work : the non linearity of the Hamiltonian with respect to the Hessian must not be very high. Therefore, the method cannot be applied directly. The method proposed by McEneaney, Kaise and Han is related to linear quadratic control problems and the value function is computed in a backward manner as a supremum of quadratic forms. However, as the time decreases, the number of quadratic forms generated by the method increases exponentially and some pruning is necessary to reduce the complexity of the algorithm. We combine the two above methods to construct a new algorithm and show that even without pruning, the complexity of the algorithm is bounded polynomially in the number of discretization time steps and in the size of the simulations of some uncontrolled stochastic processes. Numerical tests on some finance examples will be presented. More details are presented in arXiv:1605.02816.

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CP5

Endogenous Formation of Limit Order Books: Dynamics Between Trades

In this talk, I present a continuous-time extension of the framework for modeling market microstructure, developed in our previous work. We use this extension to model the shape and dynamics of the Limit Order Book (LOB) between two consecutive trades. In this model, the LOB arises as an outcome of an equilibrium between multiple agents who have different beliefs about the future demand for the asset. These beliefs may change according to the information observed by the agents (e.g. represented by a relevant stochastic factor), implying a change in the shape of the LOB. This model is consistent with the empirical observation that most of the changes in the LOB are not due to trades. More importantly, it allows one to see how changing the relevant information signal (which is given in a very general form in our model) affects the LOB.

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CP5

Robust Dynkin Game

We analyze a robust version of the Dynkin game over a set P of mutually singular probabilities. We first prove that conservative players lower and upper value coincide (Let us denote the value by V). Such a result connects the robust Dynkin game with second-order doubly reflected backward stochastic differential equations. Also, we show that the value process V is a submartingale under an appropriately defined nonlinear expectations up to the first time τ_* when V meets the lower payoff process. If the probability set P is weakly compact, one can even find an optimal triple (P_*, τ_*, γ_*) for the value V_0. This is a joint work with Erhan Bayraktar.

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CP6

Functional Ito Calculus, Path-Dependence and the Computation of Greeks

Dupire's functional Ito calculus provides an alternative approach to the classical Malliavin calculus for the computation of sensitivities, also called Greeks, of path-dependent derivatives prices. In this paper, we introduce a measure of path-dependence of functionals within the functional Ito calculus framework. Namely, we consider the Lie bracket of the space and time functional derivatives, which we use to classify functionals according to their degree of path-dependence. We then revisit the problem of efficient numerical computation of Greeks for path-dependent derivatives using integration by parts techniques. Special attention is paid to path-dependent functionals with zero Lie bracket, called weakly path-dependent functionals in our classification. We then derive the weighted-expectation formulas for their Greeks, that was first derived using Malliavin calculus. In the more general case of fully path-dependent functionals, we show that, equipped with the functional It calculus, we are able to analyze the effect of the Lie bracket on computation of Greeks. This was not achieved using Malliavin calculus. Numerical examples are also provided.

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CP6

Asymptotic Expansions for Fractional Stochastic Volatility Models

We revisit small-noise expansions in the spirit of Benarous, Baudoin-Ouyang, Deuschel-Friz-Jacquier-Violante for bivariate diffusions driven by fractional Brownian motions with different Hurst exponents. As an application, we derive small-time and tail expansions for the density of the stock price process, and for the corresponding implied volatility in a fractional stochastic volatility model. This sheds light (i) on the influence of the Hurst parameter in the time-decay of the smile and (ii) on the asymptotic behaviour of the tail of the smile, including higher orders.

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CP6

Asymptotic Optimal Strategy for Portfolio Optimization in a Slowly Varying Stochastic Environment

In this paper, we study the portfolio optimization problem with general utility functions and when the return and

volatility of underlying asset are slowly varying. An asymptotic optimal strategy is provided within a specific class of admissible controls under this problem setup. Specifically, we first establish a rigorous first order approximation of the value function associated to a fixed zeroth order suboptimal trading strategy, which is given by the heuristic argument in [J.-P. Fouque, R. Sircar and T. Zariphopoulou, Mathematical Finance, 2016]. Then, we show that this zeroth order suboptimal strategy is asymptotically optimal in a specific family of admissible trading strategies. Finally, we show that our assumptions are satisfied by a particular fully solvable model.

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CP6

A Sharp Approximation for ATM-Forward Option Prices and Implied Volatilites

We provide an approximation formula for at the money forward options based on a Polya approximation of the cumulative density function of the standard normal distribution, and prove that the relative error of this approximation is uniformly bounded for options with arbitrarily large (or small) maturities and implied volatilities. This approximation is viable in practice: for options with implied volatility less than 95% and maturity less than three years, which includes the large majority of traded options, the values given by the approximation formula fall within the tightest typical implied vol bid–ask spreads. The relative errors of the corresponding approximate option values are also uniformly bounded for all maturities and implied volatilities. The error bounds established here are the first results in the literature holding for all integrated volatilities, and are vastly superior to those of two other approximation formulas analyzed in this paper, including the Brenner–Subrahmanyam formula.

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CP7

Transform Analysis for Markov Processes and Applications: An Operator Approach

In this talk, we develop a transform analysis framework for general one dimensional Markov processes through an operator approach. Unlike the previous literature on transform analysis (e.g. affine processes, quadratic processes, etc), our analysis does not require the knowledge of a conditional characteristic function, but we only need knowledge of the infinitesimal generator of the Markov process. We characterize the joint transform of additive functionals of the Markov process and the terminal value through a functional equation. Then we develop a computational framework based on Mijatovic and Pistorius (2013) using a continuous time Markov chain (CTMC) to weakly approximate the Markov process. In the CTMC setting, the functional equations can be explicitly solved. Applications and numerical examples are also discussed.

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CP7

Parameter Estimation in Finance Using Radial Basis Function Methods

Given time series market observations for a price process, the parameters in an assumed underlying model can be determined through maximum likelihood estimation. Transition probability densities need to be estimated between each pair of data points. We show that Gaussian radial basis function approximation of the Fokker-Planck equations for the densities leads to a convenient mathematical representation. We present numerical results for one and two factor interest rate models.

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CP7

Econometric Estimation of Goodwin Growth Models

We perform econometric tests on three macroeconomic models (Goodwin, 1967, Desai, 1973 and van der Ploeg, 1985) for endogenous growth cycles using data for ten OECD countries. We evaluate these models by using relative error between the econometric estimates of the equilibrium values with its empirical average for 2 state variables - wage share and employment rate. We first address the methodological and reporting problems in Harvie, 2000 for the Goodwin Model, leading to near perfect agreement between the estimates of equilibrium employment rates and the corresponding empirical averages. The econometric estimation for van der Ploeg model incorporating CES production function further reduces the relative error for equilibrium wage share, leading to notable improvement on both dimensions. As per our knowledge, this is the first study to empirically validate the Goodwin growth models

and present satisfactory equilibrium estimates.

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CP7

Estimation of Credit Models Via Expectation Maximization and Filtering

We consider the estimation of a structural credit default model, which is based on an exponential jump-diffusion firm value process. Estimation of stable process parameters from credit derivatives poses several challenges. We use several approaches such as a nested Expectation Maximization algorithm and a non-linear filtering approach, and illustrate the estimation success in view of model complexity. We show results for several jump size distributions, such as the one-sided and the double exponential Kou model.

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MS1

Heterogeneous Treatment Effects Estimation in Finance Via Tree-Based Models

This paper investigates the use of Bayesian regression tree mod- els for estimating heterogenous treatment effects in the presence of confounding. A detailed simulation study demonstrates that non-linear regression models, which work well for prediction, can yield badly biased estimates of treatment effects when fitted to data with strong confounding. It is then shown that this bias can be alleviated by jointly modeling the treatment and the response, conditional on control variables. As an empirical illustration, a reanalysis of the Levitt crime-abortion data presented.

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MS1

Does Unusual News Forecast Market Stress?

We find that an increase in the unusualness of news with negative sentiment predicts an increase in stock market volatility. Our analysis is based on more than 360,000 articles on 50 large financial companies, mostly banks and insurers, published in 19962014. We find that the interaction between measures of unusualness and sentiment forecasts volatility at both the company-specific and aggregate level. These effects persist for several months. The pattern of response of volatility in our aggregate analysis is consistent with a model of rational inattention among investors.

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MS1

Gaussian Process Metamodels for Optimal Stopping

We discuss several new strategies for the numerical solution of optimal stopping problems within the Regression Monte Carlo (RMC) framework of Longstaff and Schwartz. First, we investigate the use of Gaussian process (GP, aka stochastic kriging) regression for fitting the continuation value. GPs offer a flexible, nonparametric regression approach that quantifies approximation quality. We also discuss extensions of GPs, including non-Gaussian observations and heteroscedastic simulation noise. Second, we explore the performance of GP probit classification models for identifying the continuation region. Third, in the context of choosing the stochastic grids used in RMC, we examine various space-filling experimental designs. We also investigate the use of batching with replicated simulations at design sites to improve the signal-to-noise ratio. Numerical case studies for valuing Bermudan Puts and Max-Calls under a variety of asset dynamics illustrate that our methods offer significant reduction in simulation budgets over existing approaches.

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MS1

Deep Learning for Limit Order Books

This paper develops a new neural network architecture for modeling spatial distributions (i.e., distributions on R^d) which is computationally efficient and takes advantage of local spatial structure. We find statistical evidence for local spatial structure in limit order books, motivating the new neural network's application to limit order books. The neural network is trained and tested on nearly 500 stocks. The neural network uses information from deep into the limit order book (i.e., many levels beyond the best bid and best ask). Techniques from deep learning such as dropout are employed to improve performance. Due to the significant computational challenges associated with the large amount of data, models are trained with a cluster of 50 GPUs. The "spatial neural network" is shown to outperform other models such as the naive empirical model, logistic regression (with nonlinear features), and a standard neural network architecture. Both neural networks strongly outperform the logistic regression model.

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MS2

Optimal Switching in Competitive Models of the Corn Ethanol Market

The growth of corn-based ethanol production in North America has been influenced by government policies including volumetric subsidies, changes in taxation, and ethanol/gasoline mix ration requirements. The growth of the ethanol industry has led to a 30% increase in corn prices over a no corn-ethanol baseline, and ethanol and corn prices have become more correlated. Managers of ethanol

plants face decisions to build/idle/restart/close their facilities. Such decisions can be considered in a real options framework, and a literature has already developed which does this modeling various price and regulatory variables as stochastic processes, is usually done assuming ethanol producers to be price takers, whose production impacts neither corn nor ethanol market prices. Here we relax the 'price taker' assumption. We develop and solve a model for the valuation and optimal operation of a collection of ethanol plants under price impact arising from their own supply and demand effects in ethanol and corn. We investigate the interplay between heterogeneity in firm costs, price impact mechanisms, price/output dynamics (possibly with hysteresis), and the potential effect that government policies might have on the real option held by ethanol producers.

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MS2

Understanding the Non-Convergence of Agricultural Futures Via Stochastic Storage Costs and Timing Options

We propose a new approach to explain the phenomenon of non-convergence between futures and spot prices in the grain markets. By incorporating stochastic spot price and storage cost, we postulate that the positive basis observed at maturity stems from the futures holder's timing options to exercise the shipping certificate delivery item and to liquidate the physical grain. An optimal double stopping problem is solved to give the optimal strategies to exercise and liquidate under two different models with mean-reverting storage rates. The solutions lead to explicit no-arbitrage prices for the shipping certificate and associated futures contract. We calibrate our models to empirical futures data during the periods of observed non-convergence.

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MS2

Risk Premia in Cash Settled Forwards

We consider the risk premia in cash settled forward contracts – the so-called Forward Freight Agreements – in the dry bulk shipping markets. We estimate the spot and forward contracts jointly using MCMC and identify the risk premium's connection to macroeconomic variables.

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MS2

Vessel Price Formation and Second-Hand Market Activity in the Dry Bulk Shipping Industry

This article investigates the joint behaviour of vessel prices, net earnings, and second-hand activity in the dry bulk shipping industry. We develop and estimate empirically a behavioural asset-pricing model with microeconomic foundations that can account for some distinct characteristics of the market. Namely, among other features, our partial equilibrium model reproducesthe actual volatility of vessel prices, the average trading activity in the market and the positive correlation between net earnings and second-hand transactions. In order to explain the formation of vessel prices, we depart from the rational expectations benchmark of the model, incorporating extrapolative expectations on the part of investors. In contrast to the majority of financial markets behavioural models, however, in our environment agents extrapolate fundamentals, not past returns. This form of extrapolation is consistent with the nature of the industry. Accordingly, we introduce two types of investors who hold heterogeneous beliefs about the cash flow process. Formal estimation of the model indicates that a heterogeneous beliefs environment, where both agent types extrapolate fundamentals, while simultaneously under(over)estimate their competitors future demand responses, can explain the positive relation between net earnings, prices and second-hand vessel transactions.

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MS3

Optimal Spread Trading Problem

We study an optimal entry-exit timing strategies for trading a pair spread which is modelled by mean-reverting process. We formulate the problem as an optimal double stopping problems and consider both infinite and finite time horizons. Three strategies are examined: 1) long to enter; 2) short to enter and 3) either long or short to enter, i.e. investor has the option to use the strategies 1 or 2. We exploit free-boundary approach and local time-space calculus 1) to obtain the closed form expressions for value functions and optimal thresholds in the perpetual case, and 2) to show analytically that optimal boundaries are monotone in time and solve uniquely nonlinear integral equations in the finite horizon case. Numerical solutions are provided and open questions are proposed.

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MS3

Multiple Optimal Stopping Approach for Com-

modity Trading with Storage

There are many commodities, with electricity being one of the more prominent at the moment, where derivatives are settled through the exchange of payment for a physical delivery of the underlying asset. In this talk, the contract is backed up by the underlying deposited in a store. I will discuss an optimal strategy for the store operator to fill up the store and sell the derivative contract assuming single or consecutive utilisation of the store for option hedging. General results will be formulated for the underlying spot price that follows a one-dimensional diffusion with natural boundaries with a detailed discussion of exponential Brownian motion, Ornstein-Uhlenbeck (OU) process and exponential OU process. The talk is based on a joint work with John Moriarty (Queen Mary University).

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MS3

Optimal Stopping Problems with Random Time-horizon Under Spectrally Negative Lvy Models

We study the optimal exercising of an American call option with a random time-horizon under exponential spectrally negative Lvy models. The random time-horizon is modelled as the so-called Omega default clock in insurance, which is the first time when the occupation time of the Lvy process below a level y exceeds an independent exponential time with mean q. We show that the shape of the value function and exercise strategy vary qualitatively with different values of y and q. In particular, we show that apart from the optimality of traditional up-crossing strategies, we may have two disconnected waiting regions for certain values of y and q, resulting in the optimality of two-sided exercise strategies. We give a complete characterisation of all optimal exercise thresholds.

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MS3

Quickest Change-Point Detection Problems for Multidimensional Wiener Processes

We study the quickest change-point detection problems for the correlated components of a multidimensional Wiener process changing their drift rates at certain random times. The optimal times of alarm are shown to be the first times at which the appropriate posterior probability processes exit certain regions restricted by the stopping boundaries. We provide estimates for the value functions and boundaries which are solutions to the appropriately constructed ordinary differential free boundary problems. (Joint work with Pavel V. Gapeev)

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MS4

Asset Values Dynamics Under Central Clearing

We develop a model of banks' asset value dynamics in a centrally cleared market with endogenous trading interactions. We show that banks have a unique equilibrium allocation of funds between their trading capitals and operating assets when they adjust trading positions to offload excess risk from their business operations. We analyze the resulting asset value processes and show that asset value concentration has the inherent tendency to increase. Our analysis points to a trade off between diversity in banks' asset values and diversification in banks' asset holdings. We investigate the impact of policies aimed at controlling asset value concentration as well as the effect of bailouts on market collateral demand.

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MS4

Multivariate Shortfall Risk Allocation and Systemic Risk

In this work, we present a risk measure designed to address the global and intrinsic risk of multidimensional interconnected system such as banks or counter-party risk in a central clearing house. The goal is two fold: on the one hand, it provides the total amount of liquidity that has to be reserved for the system to overcome financial stress situations. On the other hand, and foremost it addresses the respective amount that each member has to reserve in function of their exposure to the whole system and the systemic risk they put on the system. The analysis of the risk allocation brings some insight on the nature of the systemic risk by pointing out the elements in the financial system that are systemically relevant.

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MS4

Does OTC Derivatives Reform Incentivize Central Clearing?

The reform program for the over-the-counter (OTC) derivatives market seeks to reduce systemic risk from OTC derivatives. The reforms require that standardized OTC derivatives be cleared through central counterparties (CCPs), and they set higher capital and margin requirements for non-centrally cleared derivatives. Our objective is to gauge whether the higher capital and margin requirements adopted for bilateral contracts create a cost incentive in favor of central clearing, as intended. We introduce a model of OTC clearing to compare the total capital and collateral costs when banks transact fully bilaterally versus the capital and collateral costs when banks clear fully through CCPs. Our model and its calibration scheme are designed to use data collected by the Federal Reserve System on OTC derivatives at large bank holding companies. We find that the main factors driving the cost comparison are (i) the netting benefits achieved through bilateral and central clearing; (ii) the margin period of risk used to set initial margin and capital requirements; and (iii) the level of CCP guarantee fund requirements. Our results show that the cost comparison does not necessarily favor central clearing and, when it does, the incentive may be driven

by questionable differences in CCPs default waterfall resources.

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MS4

Central Clearing and OTC Exposures Reviewed: The Impact of Modelling Heterogeneity

Through some of the post crisis reforms of OTC derivatives markets, central counterparties (CCPs) have taken on a key role. Beyond advantages such as increased transparency, standardizing products and default management procedures, central counterparties offer a trade-off between increased multilateral netting within an asset class versus bilateral netting across asset classes. The reduction in OTC exposures brought by CCPs hence depends on factors such as (i) which and how many asset classes are cleared, (ii) how many CCPs clear these asset classes, (iii) how many members participate in the CCP, (iv) the structure of the bilateral exposure network and its netting sets. We build a heterogeneous agent type OTC derivatives network that mimics the results of recent empirical studies of these networks. Furthermore, we impose consistency conditions on the exposures in our networks, such as net zero supply of derivatives. We then proceed to show how modelling these networks at a higher degree of detail affects policy conclusions and how they differ from those implied by simpler network structures. We conclude by considering the case for FX clearing.

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MS5

Some Extensions of Model-Independent Superhedging

In a discrete-time market, we study model-independent superhedging where the semi-static superhedging portfolio consists of three parts: static positions in liquidly traded vanilla calls, static positions in other tradable, yet possibly less liquid, exotic options, and a dynamic trading strategy in risky assets under certain constraints. By considering the limit order book of each tradable exotic option and employing the MongeKantorovich theory of optimal transport we establish a general superhedging duality, which admits a natural connection to convex risk measures. With the aid of this duality, we derive a model-independent version of the fundamental theorem of asset pricing. The notion finite optimal arbitrage profit, weaker than no-arbitrage, is also introduced. It is worth noting that our method covers a large class of delta and gamma constraints.

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MS5

Robust Replication of Barrier-Style Claims on Price and Volatility

We show how to price and replicate a variety of barrier-style claims written on the log price X and quadratic variation $\langle X \rangle$ of a risky asset. Our framework assumes no arbitrage, frictionless markets and zero interest rates. We model the risky asset as a strictly positive continuous semimartingale with an independent volatility process. The volatility process may exhibit jumps and may be non-Markovian. As hedging instruments, we use only the underlying risky asset, zero-coupon bonds, and European calls and puts with the same maturity as the barrier-style claim. We consider knock-in, knock-out and rebate claims in single and double barrier varieties.

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MS5

Robust Framework for Pricing and Hedging in Discrete Time

We pursue robust approach to pricing and hedging in mathematical finance. We develop a general discrete time setting in which some underlying assets and options are available for dynamic trading and a further set of European options, possibly with varying maturities, is available for static trading. We include in our setup modelling beliefs by allowing to specify a set of paths to be considered, e.g. super-replication of a contingent claim is required only for paths falling in the given set. Our framework thus interpolates between model-independent and model-specific settings and allows to quantify the impact of making assumptions. We establish suitable FTAP and Pricing-Hedging duality results and explain how to treat further problems, such as insider trading (information quantification) or American options pricing. Based on joint works with: A. Aksamit, M. Burzoni, M. Frittelli, Z. Hou and M. Maggis.

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MS5

Constrained Optimal Transport

In the classical optimal transport problem, one is given two probability measures μ, ν on R^d and c on $\Omega := R^d \times R^d$ and looks for a map that transports μ to ν. The Kantarovich dual of this problem is to minimize $\mathcal{L}(h, g) := \int h d\mu + \int g d\nu$, over all functions h, g of R^d that satisfy the inequality $h \oplus g(z) := h(x) + g(y) \geq c(z)$ for every $z = (x, y) \in \Omega$. Then, the maximal value is the maximum $E_Q[c]$ over $\mathcal{M}(\mu, \nu)$, where a probability measure Q onΩ is in this set if it satisfies the marginal constraints

$$E_Q[h \oplus \mathbf{0}] = \int h d\mu, \quad E_Q[\mathbf{0} \oplus g] = \int g d\nu, \quad \forall\ h, g,$$

where $\mathbf{0}$ is zero function. The *martingale optimal transport on* Ω replaces the above constraint by requiring that there exists a measurable function γ such that

$$h \oplus g(z) + \gamma(x) \cdot (y - x) \geq c(z), \quad \forall z = (x, y) \in \Omega.$$

The dual of this problem is again to maximize $E_Q[c]$ over $\mathcal{Q}(\mu, \nu)$. $Q \in \mathcal{M}(\mu, \nu)$ is in this set if

$$E_Q[\gamma(x) \cdot (y - x)] = 0$$

for every bounded γ. In this talk, we outline the joint works with Dolinsky the new generalisations of these results joint obtained by Ekren.

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MS6

Pre-Committment Mean Variance: How Robust Is It?

We consider a portfolio consisting of a risk free bond and an equity index which follows a jump diffusion process. Parameters for the inflation adjusted return of the stock index and the risk free bond are determined by examining 89 years of data. The optimal dynamic asset allocation strategy for a long term pre-commitment mean variance (M-V) investor is determined by numerically solving a Hamilton-Jacobi-Bellman partial differential equation. The M-V strategy is mathematically equivalent to minimizing the quadratic shortfall of the target terminal wealth. We incorporate realistic constraints on the strategy: discrete rebalancing (yearly), maximum leverage, and no trading if insolvent. Extensive synthetic market tests, and resampled backtests of historical data, indicate that the multi-period mean variance strategy achieves approximately the same expected terminal wealth as a constant weight strategy, but with much smaller variance and probability of shortfall.

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MS6

Risk-Measure Derived Expected Utility Maximization in Dynamic Portfolio Selection

The current practice of portfolio selection has been guided by two schools of governing doctrines, a framework of expected utility maximization and a mean-risk framework. While the utility maximization framework enjoys a scientific rigor in forming a portfolio decision, it lacks appreciation from investors due to the abstract nature of global utility functions. On the other hand, while various risk measures seem intuitive to investors and are thus popular in real investment practice, some of the dynamic mean-risk frameworks display certain undesirable properties, for example, violation of the coherence, and almost all of them suffer from time inconsistency, thus resulting in computational intractability. In this research, we devote efforts to integrate the two. Under a realistic premise that investors only thoroughly understand their investment goals in terms of the mean and risk measures, we assume that investors prescribe their investment targets by setting certain attainable levels for the mean and risk measures. We then translate such mean-risk investment targets into a corresponding expected utility maximization problem which possesses favorable properties and is computationally tractable. We demonstrate in this talk certain advantages of adopting such a risk measure derived expected utility maximization framework in dynamic portfolio selection.

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MS6

Volatility-Controlled Strategies for Asset Allocation

Abstract Not Available At Time Of Publication.

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MS6

Equilibrium Strategies of a Continuous-Time Portfolio Selection Model under Rand-Dependent Utility

We study a portfolio selection model in continuous time where the preference is dictated by the rank-dependent utility. As such a model is inherently time inconsistent due to the underlying probability weighting, we consider (subgame perfect) equilibrium strategies. We provide sufficient conditions under which an equilibrium strategy can be constructed as a replicating portfolio of a final wealth. We present this final wealth explicitly, in the same form as in the classical expected utility model with the pricing kernel modified through the solution of a highly nonlinear ordinary differential equation. Finally, when the sufficient conditions do not hold, we show via an example that the equilibrium may not exist.

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MS7

Fluctuations of Diffusions Interacting Through the Ranks

We study the fluctuations of a system of diffusions interacting through the ranks when the number of diffusions goes to infinity. It is known that the empirical cumulative distribution function of such diffusions converges to a nonrandom limiting cumulative distribution function which satisfies the porous medium PDE. We show that the fluctuations of the empirical cumulative distribution function around its limit are governed by a suitable SPDE.

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MS7

Super-replication with Delayed Information: From Discrete to Continuous-Time Models

All participants in financial markets face delayed information, that is, their executed orders are made based on the information available some time before the execution time. Delay adds more uncertainty to the market, and it is of great importance to study it. In this talk, we will first discuss super replication with delayed information in a binomial model, notably, we will present a closed form formula for the price of convex contingent claims. Then, we will address the convergence problem as the time-step and delay length tend to zero and introduce analogous results in the continuous time framework. This is a joint work with Tomoyuki Ichiba.

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MS7

Market Models with Splits and Mergers

Consider a rank-based Brownian motion model of a stock market. We introduce splits and mergers in this model, so that the quantity of stocks is not constant, to make sure that this model is diverse. Under certain conditions, we show this model does not allow arbitrage.

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MS7

Information Geometry of Volatility Harvesting

Volatility harvesting refers to the idea that extra portfolio growth may be created by periodic rebalancing. For a constantly rebalanced portfolio, the excess growth rate (aka diversification return) quantifies the market volatility harvested by the portfolio. In this talk, we show that this quantity induces a new information geometry on the unit simplex which is the state space of the market weight. This geometric structure consists of a Riemannian metric and two kinds of geodesic curves on the simplex. Using this geometry, optimal rebalancing frequency can be studied in terms of a generalized Pythagorean theorem. Our approach reveals deep connections between optimal transport and information geometry, and all results can be generalized to the family of functionally generated portfolios. This is joint work with Soumik Pal.

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MS8

Mean Field Games for Strategic Servers

We study a queueing model with weakly interacting strategic servers and with reflecting boundaries under heavy-traffic. We use mean-field game techniques in order to find an asymptotic Nash equilibrium. We also use the Markov chain approximation method to construct a numerical scheme for solving the mean-field game.

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MS8

Time Discretization and Mixing in Zero-Sum Games and Problems of Model Uncertainty

In a zero-sum game without Isaacs conditions, players use mixed strategies. In the framework of continuous time, we analyze different possibilities of mixed strategies discretized in time, and the resulting value of the game.

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MS8

Optimal Investment in a Dual Risk Model

Dual risk models are popular for modeling a venture capital or high tech company, for which the running cost is deterministic and the profits arrive stochastically over time. Most of the existing literature on dual risk models concentrated on the optimal dividend strategies. In this talk, we propose to study the optimal investment strategy on research and development for the dual risk models to minimize the ruin probability of the underlying company. This is based on joint work with Arash Fahim.

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MS8

Optimal Investment in Hedge Funds Under Loss Aversion

We study optimal investment problems in hedge funds for

a loss averse manager under the framework of cumulative prospect theory. We have solved the problems explicitly for general utility satisfying the Inada conditions and piecewise exponential utility. Through a sensitivity analysis, we find that the manager will reduce the risk of the hedge fund when his/her loss aversion, risk aversion or ownership in the fund, or the management fee ratio increases. However, the increase of incentive fee ratio will drive the manager to seek more risk to achieve higher prospect utility.?

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MS9

Sparse Signals in the Cross-Section of Returns

This paper applies the least absolute shrinkage and selection operator (LASSO) to identify rare, short-lived, sparse signals in the cross-section of returns. The LASSO is an ordinary-least-squares (OLS) regression combined with a penalty function that shrinks small OLS coefficients to be exactly zero, so it is well-defined even when there are many more predictors than observations. Using the LASSO increases out-of-sample return predictability by a factor of 1.5 at the 1-minute horizon. This predictive power comes from quickly identifying the right predictors at the right time, not from better estimating the effects of some persistent factor. The LASSO typically forecasts a stock's returns using the lags of only 11 other stocks (a mere 0.5 % of all possible choices), and 90 % of these predictors last no more than 4 minutes. This success implies that returns have a sparse structure and suggests a new way of thinking about the underlying economic forces governing stock returns.

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MS9

Joint Prediction of House Prices and Mortgage Risk

In the wake of the financial crisis, the task of building accurate mortgage risk models has risen to the utmost significance. Previous research has examined the impacts of house prices on mortgage risks, as well as the impacts of adverse mortgage outcomes on house prices. Yet, modern risk models still treat house prices as simply a predictive input in modeling mortgage losses, rather than as a simultaneously determined factor. What's more, the interrelationship between house prices and mortgage risk is strongest during periods of extreme market stress, making models that omit consideration of such a factor most prone to error during periods in which errors are most costly. This project develops a machine learning framework to jointly model transitions between discrete mortgage states as well as transitions between continuous house price states. Because the likelihood of the mortgage transitions is a function of the price state, and vice versa, this problem must be approached via a joint likelihood for the multidimensional transition space. We fit our model to a data set of over 200 million mortgage loans. We assemble this data by developing computing logic to interpret over half a billion legal documents filed with county registrars of deeds throughout the country. This data enables us to pinpoint the specific addresses of each of the mortgages in question, making it possible to investigate the nuanced spatial relationships between mortgage risk and house price processes.

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MS9

Deep Autoregressive Networks for Economic Regime Dependent Asset Allocation

The relative and absolute performance of different strategy types (momentum, mean-reversion) as well their underlying asset-sector risk factors are heavily dependent on macroeconomic regimes. This allocation problem is essential to the success of multi-strategy investment frameworks. Due to the large number of potentially relevant, macro-economic and firm-specific variables involved, this becomes a high dimensional, nonlinear problem. Here we explore deep autoregressive network architectures that aid in determining and forecasting different macro performance regimes while preserving long-range temporal dependencies.

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MS9

Background Subtraction for Pattern Recognition in High Frequency Financial Data

Financial markets produce massive amounts of complex data from multiple agents, and analyzing these data is important for building an understanding of markets, their formation, and the influence of different trading strategies. We introduce a signal processing approach to deal with these complexities by applying background subtraction methods to high frequency financial data to extract significant market making behavior. In foreign exchange, for prices in a single currency pair from many sources, we model the market as a low-rank structure with an additive sparse component representing transient market making behavior. We consider case studies with real market data, showing both in-sample and online results, for how the model reveals pricing reactions that deviate from prevailing patterns. We place this study in context with alternative low-rank models used in econometrics as well as in high frequency financial models and discuss the broader implications of the melding of background subtraction, pattern recognition, and financial markets as it relates to algorithmic trading and risk. To our knowledge this is the first use of high-dimensional signal processing methods for pattern recognition in complex automated electronic markets.

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MS10

Model Risk in Gas Storage Valuation: Joint

Calibration-Estimation Risk Measurement

We present a joint calibration-estimation risk measurement methodology, extending recent literature, which incorporates both market calibration and historical estimation risk within a meaningful distributional assessment of parameter risk. We apply our technique to the problem of natural gas storage valuation, using a flexible multifactor Mean Reverting Variance Gamma model that is both forward curve consistent and calibrated to market traded options. Realistic models of the natural gas forward curve cannot be calibrated to benchmark instruments alone due to the lack of a liquid time-spread options market. We additionally devise an accessible model selection technique. For a basic one-year 20in/20out storage contract, we show that the parameter risk of our two-factor Mean Reverting Variance Gamma model is higher relative to single-factor Mean Reverting Variance Gamma and Mean Reverting Jump-Diffusion benchmarks, with very different distributional characteristics. Formally pricing the parameter risk, shows the model based bid-ask spread to be over five times that of the benchmarks. The greater flexibility of the two-factor Mean Reverting Variance Gamma model in capturing more extrinsic value therefore comes at the cost of greater uncertainty. Our novel model selection technique shows, however, this increased uncertainty to be bearable, concluding that the two-factor Mean Reverting Variance Gamma model is an acceptable choice over its one-factor counterpart.

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MS10
A Partly Sunny, Partly Windy Forecast

An analysis of how alternative energy and energy efficient devices are affecting the trading in the forward power and capacity markets. The particular focus of the discussion will be focused on forward prices and forward capacity markets.

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MS10
Trawl Processes in Finance

Trawl processes constitute a special case of so-called ambit processes and belong to the class of stationary, infinitely divisible stochastic processes. In this talk I am going to discuss key properties of this new class of stochastic processes and I will describe how they can be used in stochastic models of financial and energy markets. Also, stochastic simulation schemes and inference methods for trawl processes will be discussed and simulation studies and an empirical application will be presented.

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MS10
Polynomial Processes and Power Prices

Polynomial processes have the property that conditional expectations of polynomial functions of future state of the process can be computed explicitly (as polynomials of the current state) using matrix exponentials. Examples of polynomial diffusions include Ornstein-Uhlenbeck, CIR and Jacobi processes. We show how polynomial functions of such processes can be used to model spot and futures prices in settings such as Albertas power market, where prices are capped (at $1000/MWh), and extreme spikes have been commonplace. We also show how the polynomial-preserving properties can be used to facilitate efficient calibration to futures markets.

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MS11
Randomised Stochastic Volatility Models

Inspired by recent works on the behaviour of the forward implied volatility smile, we introduce a new class of stochastic volatility models. The dynamics are the same as the classical Heston model, but the random starting point of the variance process is randomly distributed. We show how to choose the initial distribution (i) to fit the short end of the smiletraditionally mis-calibrated in classical stochastic volatility models, and (ii) to estimate past realisation of the volatility time series. This is a joint work with Fangwei Shi (Imperial College London).

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MS11
Quantifying Mean Field Approximations for Large Games

A natural open problem in mean field game theory, especially pressing for recent models of systemic risk, is to quantify the error incurred when using a continuum of agents to approximate a model of a large but finite population. Fairly general mean rates of convergence (e.g., in Wasserstein distance) are possible, whereas deviation probabilities are much harder to estimate. In this direction, we derive a large deviation principle for the empirical measure of agents' equilibrium actions, in the simple setting of static mean field games (also known as nonatomic games). Several consequences are discussed, particularly for congestion games.

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MS11
Analytical Approximations for McKean-Vlasov Diffusions

We provide analytical approximations for the law of the solutions to a certain class of McKean-Vlasov stochastic

differential equations (MKV-SDEs) with random initial datum. "Propagation of chaos" results (Sznitman 1991) connect this class of SDEs with the macroscopic limiting behavior of a particle, evolving within a mean-field interaction particle system, as the total number of particles tends to infinity. Here we assume the mean-field interaction only acting on the drift of each particle, this giving rise to a MKV-SDE where the drift coefficient depends on the law of the unknown solution. By perturbing the non-linear forward Kolmogorov equation associated to the MKV-SDE, we perform a two-steps approximating procedure that decouples the McKean-Vlasov interaction from the standard dependence on the state-variables of the coefficients. The first step yields an expansion for the marginal distribution at a given time, whereas the second yields an expansion for the transition density. Both the approximating series turn out to be asymptotically convergent in the limit of short times and small noise. The resulting approximation formulas are expressed in semi-closed form and can be then regarded as a viable alternative to the numerical simulation of the large-particle system. Moreover, these results pave the road for further extensions of this approach to more general dynamics and to high-dimensional settings.

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MS11

Rare Events and Defualt Clustering of Large Financial Networks

The past several years have made clear the need to better understand the behavior of risk in large interconnected financial networks. Interconnections often make a system robust, but they can act as conduits for risk. In this talk, I will present recent results on modeling the dynamics of correlated default events in the financial market. An empirically motivated system of interacting point processes is introduced and we study how different types of risk, like contagion and exposure to systematic risk, compete and interact in large-scale systems. We focus on developing the related large deviations theory and on how it can be used to approximate probabilities of large losses and the most likely path to failure in large portfolios. Numerical results illustrate the accuracy of the approximation. The results give insights into how different sources of default correlation interact to generate typical and atypical portfolio losses.

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MS12

Dynamic Model of Central Counterparty Risk

A discrete time dynamic model is proposed for computation of various collateral amounts that are charged by a CCP to its members. The model accounts for variable credit ratings of the CCP members. The model also accounts for a possible default of the CCP. A key ingredient of the model is the risk measures based methodology for attribution of the default fund among the members of the CCP.

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MS12

Ice Cds Risk Management Methodology

This talk provides an overview of the ICE CDS model components, its assumptions and practical implications. ICE CDS methodology considers the market, liquidity, concentration, interest rate, index-basis, and wrong-way risks associated with Index and Single Name CDS instruments and portfolios. The CDS risk model accounts for leptokurtic and asymmetric credit spread behavior, as well as tail dependence on a portfolio level, while ensuring stability and anti-procyclicality.

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MS12

Stochastic Intensity Margin Modeling of Credit Default Swap Portfolios

Central counterparties (CCPs) calculate initial margin (IM) requirements of their members credit default swap (CDS) portfolios by statistically modeling the CDS spreads. It is well-known that the valuation of a CDS contract does require a model for the default timing of the reference entity; this is absent from the current risk management practices at CCPs. We use the stochastic intensity approach for CDS margin modeling, and show that the model can capture some important market properties of CDS spreads. Our numerical results indicate that CCPs margin estimates may substantially differ from those produced by intensity models.

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MS12

Persistence and Procyclicality In Margin Requirements

Derivatives central counterparties (CCP) impose margin requirements on their clearing members to protect the CCP from the default of a member firm. A spike in volatility leads to margin calls in times of market stress. Risk-sensitive margin requirements are procyclical in the sense that they amplify shocks. We analyze how much higher margin levels need to be to avoid procyclicality. Our analysis compares the tail decay of conditional and unconditional loss distributions to compare stable and risk-sensitive margin requirements. Greater persistence in volatility leads to a slower decay in the tail of the unconditional distribution and a higher buffer needed to avoid procyclicality.

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MS13

Distribution-Constrained Optimal Stopping

We solve the problem of optimal stopping of a Brownian motion subject to the constraint that the stopping time's distribution is a given measure consisting of finitely-many atoms. In particular, we show that this problem can be converted to a finite sequence of state-constrained optimal control problems with additional states corresponding to the conditional probability of stopping at each possible terminal time. The proof of this correspondence relies on a new variation of the dynamic programming principle for state-constrained problems which avoids measurable selection. We emphasize that distribution constraints lead to novel and interesting mathematical problems on their own, but also demonstrate an application in mathematical finance to model-free superhedging with an outlook on volatility.

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MS13

Level, Slope, and Curvature Trading in Yields and Volatilities

We compare and contrast a yield curve with a vol smile. We develop a simple framework to guide trading in either the level, slope, or curvature of each structure.

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MS13

Super-Replication in Extremely Incomplete Markets

In this work we introduce the notion of extremely incomplete markets. We prove that for these markets the superreplication price coincide with the model free superreplication price. Namely, the knowledge of the model does not reduce the superreplication price. We provide two families of extremely incomplete models: stochastic volatility models and rough volatility models. Moreover, we give several computational examples. Our approach is purely probabilistic. (joint work with A.Neufeld)

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MS13

Variance Swaps on Time-Changed Markov Processes

We prove that a variance swap has the same price as a co-terminal European-style contract, when the underlying is a Markov process, time-changed by a general continuous stochastic clock, which is allowed to have general correlation with the driving Markov process, which is allowed to have state-dependent jump distributions. The European contract's payoff function satisfies an ordinary integro-differential equation, which depends only on the dynamics of the Markov process, not on the clock. In some examples, the payoff function that prices the variance swap can be computed explicitly. Joint work with Peter Carr and Matt Lorig.

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MS14

Optimal Mean-Variance Portfolio Allocation: a Hamilton-Jacobi-Bellman Pde Approach

In this talk, we discuss a numerical Hamilton-Jacobi-Bellman partial differential equation approach for the mean-variance portfolio allocation problem under jump diffusion models. The focus of this talk is on realistic portfolio constraints, jumps in the risky asset, and a semi-self-financing strategy which involves positive cash withdrawals but gives superior results in terms of mean-variance criteria. This is a joint work with P. Forsyth (Waterloo, Canada)

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MS14

Optimal Control of Conditional Value-at-Risk in Continuous Time

We consider continuous-time stochastic optimal control problems featuring Conditional Value-at-Risk (CVaR) in the objective. The major difficulty in these problems arises from time-inconsistency, which prevents us from directly using dynamic programming. To resolve this challenge, we convert to an equivalent bilevel optimization problem in which the inner optimization problem is standard stochastic control. Furthermore, we provide conditions under which the outer objective function is convex and differentiable. We compute the outer objective's value via a Hamilton-Jacobi-Bellman equation and its gradient via the viscosity solution of a linear parabolic equation, which allows us to perform gradient descent. The signifi-

cance of this result is that we provide an efficient dynamic programming-based algorithm for optimal control of CVaR without lifting the state-space. To broaden the applicability of the proposed algorithm, we propose convergent approximation schemes in cases where our key assumptions do not hold and characterize relevant suboptimality bounds. In addition, we extend our method to a more general class of risk metrics, which includes mean-variance and median-deviation. We also demonstrate a concrete application to portfolio optimization under CVaR constraints. Our results contribute an efficient framework for solving time-inconsistent CVaR-based dynamic optimization.

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MS14

Efficient Numerical Methods and Comparisons for Pre-Commitment and Time-Consistent Mean-Variance Asset Allocation

We have developed a simulation-based approach for solving the constrained dynamic mean-variance portfolio management problem. Efficient algorithms for the target-based pre-commitment as well as for the time-consistent dynamic strategy have been developed and analysed. For this dynamic optimization problem, we first consider a sub-optimal strategy, called the multi-stage strategy, which can be utilized in a forward fashion. Then, based on this fast yet sub-optimal strategy, we propose an approach to improve the solution, based on the backward recursive programming. We design the backward recursion algorithm such that the result is guaranteed to converge to a solution, which is at least not worse than the one generated by the multi-stage strategy. In our numeric tests, highly satisfactory asset allocations can be achieved for the dynamic portfolio management problem in case various constraints are cast on the control variables.

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MS14

On Time Consistency for Mean-variance Portfolio Selection

We consider the mean-variance portfolio selection problem in continuous time, and compare three different approaches to deal with its time inconsistency: the precommitment approach solved by Zhou and Li (2000); the game theoretical approach, introduced by Basak and Chabakauri (2010) and Bjork and Murgoci (2010); and the dynamically optimal approach introduced by Pedersen and Peskir (2016).

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MS15

Resolving Time Inconsistency Through a Competition Scheme

The salespersons, whose time preferences are described by quasi-hyperbolic discounting functions, tend to evaluate the payoff received in the future with a relative large discount factor. Then, the salespersons suffer from time inconsistency and prefer exerting relative small effort in multiperiod product sales. Thus, to motivate the salespersons, the company may design a competition scheme, under which the winner can receive a marginal profit benefit with higher probability. We construct the mathematical model for the competition scheme and study its influence on the time inconsistency and the total welfare of the salespersons' group. With detailed analysis, we have shown that the competition scheme with suitable attraction can improve the time inconsistency and the total welfare of the group. However, the competition scheme with large attraction makes the time inconsistency of the group worse. When the difference between the salespersons' time preference is large enough (or small enough), the competition scheme with large attraction may improve (or worsen) the total welfare of the group.

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MS15

Realization Utility with Adaptive Reference Points

Abstract Not Available At Time Of Publication.

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MS15

Optimal Stopping Strategies of A Behavioral Gambler in Finite Time Horizon

The optimal casino gambling of infinite time horizon has been well studied by He et al. (2015a) and He et al. (2015b). In this paper we present the systematic solution to the finite time optimal casino betting problem. The accompanied Skorokhod embedding in the finite time arises due to the change of the decision variable from the stopping time to the probability distribution function of the gains or losses at the exit time. In solving this auxiliary embedding problem we introduce the randomized Root stopping time and show the necessary and sufficient conditions for which the stopping time exists given the distribution. We also demonstrate the optimality properties satisfied by the Root stopping time as well as its associated potential function, which reveals that the Root stopping time on average spends least of steps before exit among all the feasible stop-

ping strategies with the same distribution.

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MS15

Long-Term Growth Rate of Expected Utility for Leveraged ETFs

In this talk, we discuss the long-term growth rate of expected utility from holding a leveraged exchanged-traded fund (LETF). Working with the power utility function, we develop an analytical approach that employs martingale extraction and involves finding the eigenpair associated with the infinitesimal generator of a time-homogeneous Markov diffusion. We provide the analytic long-term growth rate under a number of models for the reference asset, including the inverse GARCH model, extended CIR model, quadratic model, as well as the Heston and 3/2 stochastic volatility models. We also investigate the impact of stochastic interest rate, and determine the optimal leverage ratio for the long-term investor.

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MS16

Systemic Influences on Optimal Equity-Credit Investment

Recent events have shown that the dependence structure of financial markets is more complex than what is captured by classical models. For example, during the 2008 financial crisis, the financial instability of some companies spread out to affect other companies. The goal of this talk is to analyze how such systemic influences are reflected in optimal investment decisions. To this end, we introduce a model with dependence structure between market risk and default risk of the companies. An investor can use stocks and credit default swaps (CDSs) to participate in the market. We derive an explicit expression for the optimal investment strategy in stocks and CDSs. This allows us to analyze the mechanisms driving the optimal investment decisions. We then develop a novel calibration procedure so that we can fit the model to historical time series of stock and CDS data. An empirical analysis reveals the critical role of systemic risk in portfolio monitoring.

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MS16

A Second-Order Expansion of the Value Function in the Problem of Optimal Investment in Incomplete Markets

In the framework of incomplete financial market where the stock price dynamics is modeled by a continuous semimartingale, an explicit quadratic expansion for the power investor's value function and a first-order expansion for the corresponding optimal wealth process - seen as a function of the underlying market price of risk process - are provided. An example illustrating the result is also given. The talk is based on the joint work with Kasper Larsen, Mihai Sirbu, and Gordan Zitkovic.

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MS16

Optimization Problem for a Portfolio with an Illiquid Asset: Lie Group Analysis

One of the ways to model illiquidity among others is to build an optimization problem and assume that one of the assets in a portfolio can not be sold until a certain finite, infinite or random moment of time. Working in the Merton's optimal consumption framework with continuous time we consider an optimization problem for a portfolio with an illiquid, a risky and a risk-free asset. Our goal is to carry out a complete Lie group analysis of PDEs describing value function and investment and consumption strategies for a portfolio with an illiquid asset that is sold in an exogenous random moment of time with a prescribed liquidation time distribution. The problem of such type leads to three dimensional nonlinear Hamilton-Jacobi-Bellman (HJB) equations. To reduce the three-dimensional problem to a two-dimensional one or even to an ODE one usually uses some substitutions, yet the methods used to find such substitutions are rarely discussed by the authors. We find the admitted Lie algebra for a broad class of liquidation time distributions in cases of HARA and log utility functions and formulate corresponding theorems for all these cases. We use found Lie algebras to obtain reductions of the studied equations. Several of similar substitutions were used in other papers before whereas others are new to our knowledge. This method gives us the possibility to provide a complete set of non-equivalent substitutions and reduced equations.

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MS16

Optimal Investment with Transaction Costs Under Cumulative Prospect Theory in Discrete Time

Abstract Not Available At Time Of Publication.

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MS17

Algorithmic Trade Execution and Market Dynamics

Abstract Not Available At Time Of Publication.

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MS17

A Deep Neural Network based Trade Recommendation Engine

Trading firms seek to use machine learning to recommend when to enter into or exit a trade, especially when low latency of execution is not the most dominant factor in generating alpha. Using tick level limit order book updates for treasure bond futures, this talk describes the process of feature extraction and labelling to train deep neural network classifiers for trade entry or exit. Preliminary strategy backtesting results are provided.

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MS17

Do U.S. Financial Regulators Listen to the Public? Testing the Regulatory Process with the RegRank Algorithm

We examine the notice-and-comment process and its impact on influencing regulatory decisions by analyzing the text of public rule-making documents of the Commodity Futures Trading Commission (CFTC) and associated comments. For this task, we develop a machine learning framework and an algorithm called RegRank, which learns the thematic structure of regulatory rules and public comments and then assigns tone weights to each theme to come up with an aggregate score for each document. Based on these scores we test the hypothesis that the CFTC adjusts the final rule issued in the direction of tone expressed in public comments. Our findings strongly support this hypothesis and further suggest that this mostly occurs in response to comments from the regulated financial industry. We posit that the RegRank algorithm and related text mining methods have the potential to empower the public to test whether it has been given the "due process" and hence keep government agencies in check.

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MS17

Modeling Path Dependent Mortgage Prepayment using Recurrent Neural Networks

We develop deep recurrent neural networks for modeling mortgage prepayment risk. Mortgage prepayment behavior is highly path dependent. Past behavior of the mortgage borrower given previous delinquency scenarios and opportunities to refinance reveal the borrowers predisposition. Recurrent neural networks form a class of models that are designed to take advantage of such path dependence. We compare the performance of recurrent neural networks with other competing approaches, such as standard feedforward neural networks and logistic regression. The recurrent neural network as well as the competing models are embedded within a dynamic Markov model for the mortgage state transitions.

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MS18

Spread Option Prices, Strike Conventions and Implied Correlation

The classical Margrabe formula for spread option pricing (along with well-known extensions such as Kirk's formula) is widely used for convenient and rapid derivative pricing and physical asset valuation in commodity markets. Implied correlations are even sometimes quoted from market prices based on the underlying assumption of two lognormal processes. However, key inputs in this approach are the volatility parameters for each of the commodity prices, often chosen from the market via implied volatility observations. Which strike should one use for the implied volatility of each component of the spread? Heuristic or ad hoc rules are often applied, and surprisingly few have rigorously analyzed this question despite its high practical relevance. We present here a novel theoretical approach to tackling this challenge, by deriving an optimal choice of 'strike convention' in the case of the Heston model, based on choosing the implied volatility such that implied correlations best match 'true' (historically estimated) correlations across a range of moneyness. Building on asymptotic expansion results, Malliavin calculus tools and approximation techniques, we analyze the performance of different strike conventions for commodity spread option pricing across a variety of cases of maturity, moneyness, and implied volatility structures.

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MS18

Structural Estimation of Switching Options

We use structural estimation to determine the one-time costs associated with shutting down, restarting, and abandoning peak power plants in the United States. The sample period covers 2001-2009. The approach combines a nonparametric regression for capturing transitions in the exogenous state variable with a one-step nonlinear optimization for structural estimation. The data are well-suited to test the new method because the state variable is not described by any known stochastic process. Our results provide useful estimates of maintenance and switching costs for peak power plants.

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MS18

Portfolio Risk: A Retailer's Perspective

In this talk, we will provide a practitioner perspective to some of the more interesting types of portfolio risks we face in the retail electricity industry and how we mitigate and hedge them. For example, we will discuss how we handle massive volumes of customer data to produce various types of load forecasts.

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MS18

How Good Are "Natural" Hedges?

The subject matter will relate to recent trends of IPPs, utilities and even now PE shops to try to balance their natural long positions with natural shorts (e.g. retail). This solves some problems and causes others.

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MS19

"Exchange-Traded Funds and Related Strategies

Abstract Not Available At Time Of Publication.

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MS19

Large-Dimensional High-Frequency Factor Analysis

This paper develops a statistical theory to estimate an unknown factor structure based on financial high-frequency data. I derive a new estimator for the number of factors and derive consistent and asymptotically mixed-normal estimators of the loadings and factors under the assumption of a large number of cross-sectional and high-frequency observations. The estimation approach can separate factors for normal continuous and rare jump risk. The estimators for the loadings and factors are based on the principal component analysis of the quadratic covariation matrix. The estimator for the number of factors uses a perturbed eigenvalue ratio statistic. The results are obtained under general conditions, that allow for a very rich class of stochastic processes and for serial and cross-sectional correlation in the idiosyncratic components.

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MS19

When Arma Meets High Frequency Data: An Integrated Theory

In this paper, we propose a general framework of volatility estimation with noisy high-frequency data. Our likelihood-based strategy relies on a misspecified ARMA model with homoscedastic innovations. We show that the exact quasi-likelihood estimator is consistent with respect to the quadratic variation of the data generating process, a general Ito-semimartingale, and that the estimator is asymptotically mixed normal. We also provide the asymptotic theory of estimators of the reduced-form parameters in the ARMA model, which capture the temporal dependence of the microstructure noise. In contrast, we show that the classical Whittle estimator is inconsistent. Finally, we discuss model selection, estimation efficiency, and extensions to irregular sampling and jumps.

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MS19

Estimation of the Continuous and Discontinuous Leverage Effects

This paper examines the leverage effect, or the generally negative covariation between asset returns and their changes in volatility, under a general setup that allows the log-price and volatility processes to be Itô semimartingales. We decompose the leverage effect into continuous and discontinuous parts and develop statistical methods to estimate them. We establish the asymptotic properties of these estimators. We also extend our methods and results to the situation where there is market microstructure noise in the observed returns. We show in Monte Carlo simulations that our estimators have good finite sample performance. When applying our methods to real data, our empirical results provide convincing evidence of the presence of the two leverage effects, especially the discontinuous one.

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MS20

Default Cascades in Inhomogeneous Financial Networks

Propagation of balance-sheet or cash-flow insolvency across

financial institutions may be modeled as a cascade process on a network representing their mutual exposures. We derive rigorous asymptotic results for the magnitude of contagion in a large financial network and give an analytical expression for the asymptotic fraction of defaults, in terms of network characteristics. Our results extend previous studies on contagion in random graphs to inhomogeneous directed graphs with a given degree sequence and arbitrary distribution of weights. We introduce a criterion for the resilience of a large financial network to the insolvency of a small group of financial institutions and quantify how contagion amplifies small shocks to the network. Our results emphasize the role played by 'contagious links' and show that institutions which contribute most to network instability in case of default have both large connectivity and a large fraction of contagious links. We then allow for random recovery rates for the exposures to defaulted banks and give sufficient conditions such that the size of first order cascade due to contagious links in different networks to be small. This is joint work with Rama Cont and Andreea Minca.

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MS20

Systemic Risk under Heterogeneous Beliefs

We consider an interbank network of bilateral exposures, where each bank only knows its own contracts but not the exposures between other pairs of banks. Defaults are costly and may lead to financial contagion that spreads through the network. We model this spread of insolvency as a dynamic game, where banks have the ability to intervene and join a rescue consortium to save the insolvent banks. Banks will do so only if an intervention is incentive compatible given their beliefs on the network, that is, their share of the bailout costs is believed to be smaller than their losses incurred due to future defaults in the system. We analyze the set of sequential equilibria in these games with heterogeneous beliefs and contrast the results to the equilibrium outcomes with complete information. We show that incomplete information may lead to a failure of coordination and trigger a systemic default which could have been avoided in presence of complete information.

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MS20

Systemic Risk and Central Clearing Counterparty Design

We examine the effects on a financial network of multilateral clearing via a central clearing counterparty (CCP) from an ex ante and ex post perspective. The CCP is capitalized with equity and a guarantee fund and it can charge a volume-based fee. We propose a design of the CCP, under which it improves aggregate surplus, and reduces banks' liquidation and shortfall losses. We provide sufficient conditions in terms of the CCP's equity, fee and guarantee fund policy for a reduction of systemic risk. Moreover, we prove existence of a range for these policies which are at the same time incentive compatible and systemic risk mitigating. A simulation study based on real market data shows that central counterparty clearing can reduce systemic risk and improve banks' utility. (Joint with Hamed Amini and Damir Filipovic)

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MS20

Sensitivity of the Eisenberg-Noe Network Model to the Relative Liabilities

The Eisenberg-Noe algorithm gives a clearing payment vector for a system of interconnected financial institutions in which some banks are unable to fulfill their obligations to other banks in full. The network model takes as input a relative liability matrix which gives the liabilities owed from each bank to its counterparties. In practice, these liabilities are generally unknown and must be estimated. We perform sensitivity analysis on this relative liability matrix and obtain a worst-case scenario in terms of the payoff to a "society' node. We begin by defining a set of admissible matrices that perturb the true relative liability matrix. We define a directional derivative of the Eisenberg-Noe clearing vector with respect to the perturbation matrix. We maximize this directional derivative to obtain a worst-case perturbation matrix that provides an upper bound on the estimation error. Finally, we illustrate our results on an EBA dataset of European banks.

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MS21

Model Uncertainty, Recalibration, and the Emergence of Delta-Vega Hedging

We study option pricing and hedging with uncertainty about a Black-Scholes reference model which is dynamically recalibrated to the market price of a liquidly traded vanilla option. For dynamic trading in the underlying asset and this vanilla option, delta-vega hedging is asymptotically optimal in the limit for small uncertainty aversion. The corresponding indifference price corrections are determined by the disparity between the vegas, gammas, vannas, and volgas of the non-traded and the liquidly traded

options.

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MS21

Hedging with Small Uncertainty Aversion

We study the pricing and hedging of derivative securities with uncertainty about the volatility of the underlying asset. Rather than taking all models from a prespecified class equally seriously, we penalise less plausible ones based on their "distance" to a reference local volatility model. In the limit for small uncertainty aversion, this leads to explicit formulas for prices and hedging strategies in terms of the security's cash gamma.

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MS21

High-Roller Impact: A Large Generalized Game Model of Parimutuel Wagering

How do large-scale participants in parimutuel wagering events affect the house and ordinary bettors? A standard narrative suggests that they may temporarily benefit the former at the expense of the latter. To approach this problem, we begin by developing a model based on the theory of large generalized games. Constrained only by their budgets, a continuum of diffuse (ordinary) players and a single atomic (large-scale) player simultaneously wager to maximize their expected profits according to their individual beliefs. Our main theoretical result gives necessary and sufficient conditions for the existence and uniqueness of a pure-strategy Nash equilibrium. Using this framework, we analyze our question in concrete scenarios. First, we study a situation in which both predicted effects are observed. Neither is always observed in our remaining examples, suggesting the need for a more nuanced view of large-scale participants.

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MS21

Arbitrage in Non-dominated Markets with Frictions

We prove a Fundamental Theorem of Asset Pricing for a multidimensional discrete time financial market where trading is subject to proportional transaction cost, and the asset price dynamic is modeled by a family of probability measures for which a dominating measure may be absent. This can be seen as a non-dominated martingale selection problem, which we solve using a backward-forward scheme. I will illustrate how the theory of analytic sets helps us to overcome measurability issues introduced by the backward-forward scheme.

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MS22

Approximation of the Value of Contracts in Insurance Liabilities using Radial Basis Functions

We introduce the Option Interpolation Model for approximating embedded option values in insurance liabilities. Such a method is important for risk management applications such as Asset & Liability Management and Own Risk Solvency Assessment in Solvency II. The proposed method is based on interpolation via radial basis functions, which have the advantage of being able to interpolate scattered data. We re-write the involved calibration problem into a State Space Hidden Markov model, which enables the use of existing calibration techniques. To improve computation time we construct a novel method to determine the interpolation weights when extra interpolation points are added. Using a number of tests, we show convergence is greatly improved compared to the benchmark model.

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MS22

Mean Variance Asset Allocation under Mean Reverting Growth Rate

Efficient frontiers between expected wealth and its variance are sought at given future time. Available assets are riskless bond and stock index following geometrical Brownian motion with a mean reverting growth rate following the Ornstein–Uhlenbeck process. The resulting two-dimensional convection-diffusion problem has the as-

set split controlling the coefficients. Robust and accurate solution of these control problems is considired. Numerical experiments show efficient asset allocation frontiers with and without mean reverting growth rate.

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MS22

Mortgage Refinancing Strategies

In this research, we investigate strategies for the debtors in view of balancing the profit and risk under the condition of refinancing. We establish a utility optimization problem consisting of the expectation and variance of the discounted profit of refinancing. Optimal solutions are discussed and formulated if the dynamic of the interest rate follows the CIR model. Tools in stochastic analysis and optimization are used in our study.

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MS22

Optimal Reinsurance and Investment Strategies under the Effect of Inside Information: Stochastic Differential Game Formulation

This work develops a non-zero-sum differential investment and reinsurance game between two insurance companies in the presence of inside information, in which each insurance company is assumed to maximize the utility by adopting the optimal investment and reinsurance strategies. The utility function consists of the company's terminal surplus and the difference between its own and the competitor. Moreover, at the beginning of the game, some inside information about the future realizations of one company is available for both companies. In this paper, we employ the enlargement of filtration techniques to treat the inside information. The existence of the Nash equilibrium for the game is verified. In addition, for the case of an exponential utility, we obtain the optimal strategies by dynamic programming approach and the numerical method. Some numerical examples are provided to illustrate how the investment-reinsurance strategies change when the model parameters vary.

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MS23

Risk-Averse Multi-Objective Two-Stage Stochastic Programming

Risk-averse two-stage stochastic programming is concerned with the minimization of a risk measure of a random cost function over the feasible choices of a deterministic and a random decision variable. We study the multiobjective version of this problem in which case the cost function is vector-valued and its risk is quantified via a set-valued risk measure. Although the resulting problem has a set-valued objective function, we reformulate it as a convex vector optimization problem and propose a customized version of Bensons algorithm to solve it. In particular, we develop convex duality-based cutting-plane type methods to solve the scalar subproblems appearing in Bensons algorithm. The algorithm is illustrated on examples including the portfolio optimization problem with transaction costs where the set-valued risk measure is a utility-based shortfall risk measure.

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MS23

Scalarizations of Set-Valued Risk Measures

Set-valued risk measures have been considered for measuring risk in markets with transaction costs and systemic risk. In this talk we will consider the scalarizations of set-valued risk measures. This will cover primal and dual representations and a one-to-one relation between set-valued risk measures and the family of scalarizations. Special emphasis will be given to the equivalence of recursive relations for the family of scalarizations for dynamic set-valued risk measures to multiportfolio time consistency.

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MS23

Dynamic Systemic Risk Measures

The question of measuring and managing systemic risk - especially in view of the recent financial crises - became more and more important. We study systemic risk by taking the perspective of a financial regulator and considering the axiomatic approach. The aim of this paper is to generalize the static approach and analyze systemic risk measures in a dynamic setting. We work in the framework for bounded discrete-time processes. Apart from the possibility to consider the evolution of financial values, another important advantage of the dynamic approach is the possibility to incorporate information in the risk measurement and management process. In context of this dynamic setting we also discuss the arising question of time-consistency for our dynamic systemic risk measures.

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MS23

Utility Indifference Pricing for Incomplete Preferences Via Convex Vector Optimization

Utility indifference pricing theory is well studied for complete preferences that can be represented by a single utility function. Moreover, it is known that incomplete preferences can be represented by a single-utility multi-prior or multi-utility single-prior representations under some assumptions, see [E. Ok, P. Ortoleva, and G. Riella. *Incomplete preferences under uncertainty: indecisiveness in beliefs versus tastes.* 2012]. Under both representations, it is possible to see the utility maximization problem as a convex vector optimization problem. We allow utility functions to be multivariate and we define the utility buy and sell prices as set valued functions of the claim. Utility indifference price bound is defined accordingly. It has been shown that the buy and sell prices recover the complete preference case where the utility function is univariate. Moreover, buy and sell prices satisfy some monotonicity and convexity properties as expected. It is possible to compute these set valued prices by solving two convex vector optimization problems.

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MS24

On Time Inconsistent Control and Equilibrium Theory

We develop a theory for continuous time stochastic control problems, which, in various ways, are time inconsistent. For a general controlled continuous time Markov process and a fairly general objective functional we derive an extension of the standard Hamilton-Jacobi-Bellman equation. We apply the developed theory to a rather detailed study of a general equilibrium model of an endowment economy with dynamically inconsistent preferences that is not limited to the particular case of non-exponential discounting. Our main objective is an explicit characterization of the equilibrium within a general setting, including the state price density, market price of risk and the equilibrium short rate. The talk is partly based on joined work with Tomas Bjork and Agatha Murgoci.

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MS24

Dynamic Approaches for Some Time Inconsistent Problems

We investigate possible approaches to study general time-inconsistent optimization problems without assuming the existence of optimal strategy. This leads immediately to the need to refine the concept of time-consistency as well as any method that is based on Pontryagin's Maximum Principle. The fundamental obstacle is the dilemma of having to invoke the *Dynamic Programming Principle* (DPP) in a time-inconsistent setting, which is contradictory in nature. The main contribution of this work is the introduction of the idea of the "dynamic utility" under which the original time inconsistent problem (under the fixed utility) becomes a time consistent one. As a benchmark model, we shall consider a stochastic controlled problem with multidimensional backward SDE dynamics, which covers many existing time-inconsistent problems in the literature as special cases, and we argue that the time inconsistency is essentially equivalent to the lack of *comparison principle*. We shall propose three approaches aiming at reviving the DPP in this setting: the duality approach, the dynamic utility approach, and the master equation approach. Unlike the game approach in many existing works in continuous time models, all our approaches produce the same value as the original static problem.

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MS24

Time-Consistent Stopping

We provide the theoretical grounds for obtaining new types of implementable stopping solution in time-inconsistent stopping problems. Those solutions are based on a sequential non-cooperative game modeling of the stopping problem. We will insist on the difference between the control case and the stopping framework. We illustrate in particular our theory with non-exponential discounting in a real option framework, and cumulative prospect theory for the casino gambler problem.

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MS25

Extension and Calibration of a Hawkes-Based Optimal Execution Model

Abstract Not Available At Time Of Publication.

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MS25

Liquidating Baskets of Co-Moving Assets

Abstract Not Available At Time Of Publication.

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MS25

Rough Volatility and Leverage Effect: From High Frequency Foundations to Smile

It has been recently shown that rough volatility models reproduce very well the statistical properties of low frequency financial data. In such models, the volatility process is driven by a fractional Brownian motion with Hurst parameter of order 0.1. Furthermore, it is very well-known that volatility and price movements are correlated, through the so-called leverage effect phenomenon. The goal of this talk is first to explain how fractional dynamics and leverage effect can be obtained from the behaviour of market participants at the microstructural scales. Using Hawkes processes, we show that these features naturally arise in the presence of high frequency trading under no arbitrage condition. Then we will demonstrate that such result enables us to derive an efficient method to compute the smile in rough volatility models. This is joint work with Omar El Euch, Masaaki Fukasawa, Jim Gatheral and Thibault Jaisson.

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MS25

A Pure-Jump Market-Making Model for High-Frequency Trading, with Numerics

Abstract Not Available At Time Of Publication.

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MS26

Commodity Market Financialization, Indexation, and Correlation

The phenomenon of 'financialization' of commodity markets – the participation of banks, pension funds, hedge funds, and other financial investors in commodity markets – has grown dramatical during this millennium. One form of financialization is index investing, whereby investors take positions in derivatives that have a payoff tied to an index of commodities. Since index investors buy and sell many commodities simultaneously, it is widely believed that they have caused increases in correlations across commodity prices. This paper investigates this intuition using variants of a canonical model of hedging and speculation. The models demonstrate that the common intuition is not generally correct, and that increased index investing can lead to lower correlations between commodity prices. Regardless of the effect of index investing (and financialization generally) on correlations, the models imply that they are welfare improving because they improve the allocation of risk. Thus, correlation is an improper metric to measure the impact of financialization on welfare.

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MS26

Risk and Expected Return in the Oil-Futures Market

This talk will combine two aspects of the crude-oil futures market, expected returns and risk. Defining forward-looking betas as perturbations of historical estimates, we use the market prices of equity, index and commodity options under a single-factor market model to estimate the appropriate forward-looking perturbation to apply to the historical beta. Using this forward-looking measure of the correlation between crude-oil and the S&P 500 together with forward-looking (i.e., implied) volatilities on commodities and stock-market indices, we compute an ex-ante estimate of the expected future crude-oil spot price through the use of an equity ex-ante risk premium and the conditional CAPM. Using market prices for crude-oil futures options and the prices of their underlying futures contracts, we calibrate the volatility skew using the Merton (1976) jump-diffusion option-pricing model. We demonstrate the jump-diffusion parameters bear a close relationship to concurrent economic, financial and geopolitical events. The postulated Merton-style model is shown to yield useful parameters from which market prices can be computed, option prices can be marked-to-market and (imperfectly) hedged, and an informationally-rich structure covering the turbulent post-2007 time period obtained.

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MS26

Energy Prices and Dynamic Games with Stochastic Demand

The dramatic decline in oil prices, from around $110 per barrel in June 2014 to around $30 in January 2016 highlights the importance of competition between different energy sources. Indeed, the price drop has been primarily attributed to OPEC's strategic decision not to curb its oil production in the face of increased supply of shale gas and oil in the US. Most dynamic Cournot models focus on supply-side factors, such as increased shale oil, and random discoveries. However reduced and uncertain demand from China is a major factor driving oil price volatility. We study Cournot games in a stochastic demand environment, and present asymptotic and numerical results, as well as a modified Hotelling's rule for games with stochastic demand.

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MS26

Planning and Operation of a Large US Onshore Oil and Gas Portfolio; Problems and Experiences

This talk is about the challenges in operation of an onshore oil and gas portfolio from an industry point of view.

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MS27

Optimal Investment with Transaction Costs and Stochastic Volatility

Two major financial market complexities are transaction costs and uncertain volatility, and we analyze their joint impact on the problem of portfolio optimization. When volatility is constant, the transaction costs optimal investment problem has a long history, especially in the use of asymptotic approximations when the cost is small. Under stochastic volatility, but with no transaction costs, the Merton problem under general utility functions can also be analyzed with asymptotic methods. Here, we look at the final time optimal investment and consumption problem, when both complexities are present, using separation of time scales approximations. We find the first term in the asymptotic expansion in the time scale parameter, of the optimal value function, consumption, and of the optimal strategy, for fixed small transaction costs. We give a proof of accuracy in the case of fast mean-reverting stochastic volatility. Additionally, we deduce the optimal long-term growth rate.

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MS27

Portfolio Optimization with Recursive Utility under Small Transaction Costs

We investigate the portfolio problem of an investor with Epstein-Zin recursive utility under proportional transaction costs. We characterize the solution via variational inequalities and prove existence of classical solutions for small cost parameters. We also provide a suitable verification theorem. This allows us to derive rigorous asymptotic expansions for optimal no-trade regions and consumption strategies and to investigate the effects of the investors relative risk aversion and the elasticity of intertemporal substitution (EIS) ψ on the optimal strategies. Our main findings are: (a) At the leading order, the no-trade region is the same as with additive expected utility; in particular, it is determined solely by the relative risk aversion. The no-trade region depends on the investors EIS only at the next-to-leading order, and only indirectly thought the frictionless optimal consumption rate. (b) The investors optimal consumption depends on his EIS also at the leading order. The consumption-wealth ratio is higher than in the frictionless case if and only if $\psi > 1$.

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MS27

Asymptotic Methods for Transaction Costs

We will consider the classical optimal investment and consumption problem with infinite horizon is studied in the presence of both proportional and fixed costs with general utility functions. In this context, we outline general results for possibly discontinuous viscosity solutions of the dynamic programming equation. Then, discuss asymptotic and numerical methods for these problems. Applications to markets with other types of frictions will also be given.

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MS27

On the Market Viability under Proportional Transaction Costs

This paper studies the market viability with proportional transaction costs. Instead of requiring the existence of strictly consistent price systems (SCPS) as in the literature, we show that strictly consistent local martingale systems (SCLMS) can successfully serve as the dual elements such that the market viability can be verified. We introduce two weaker notions of no arbitrage conditions on market models named no unbounded profit with bounded risk (NUPBR) and no local arbitrage with bounded portfolios (NLABP). In particular, we show that the NUPBR and NLABP conditions in the robust sense for the smaller bid-ask spreads is the equivalent characterization of the existence of SCLMS for general market models. We also discuss the implications for the utility maximization problem.

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MS28

Risk Sensitive Asset Management and Cascading Defaults

Abstract Not Available At Time Of Publication.

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MS28

Robust Optimization of Credit Portfolios

Abstract Not Available At Time Of Publication.

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MS28

Robustness Issues in Risk Estimation

Abstract Not Available At Time Of Publication.

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MS28

Timeconsistent Investment under Model Uncertainty: The Robust Forward Criteria

Abstract Not Available At Time Of Publication.

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MS29

Double Spiral Method, the Generalized Hilbert Transform and Fast Pricing of Asian and Barrier Options

We construct a new accurate and fast method (Double Spiral method) for realization of operator $\Pi^+ := \mathcal{F}\mathbf{1}_{(0,+\infty)}\mathcal{F}^{-1} = (1/2)(I - \sqrt{-1}\mathcal{H})$, where $\mathcal{H}$ and $\mathcal{F}$ are the Hilbertcand Fourier transforms, in backward induction procedures used to price options with barrier and lookback features, and Asians with discrete sampling. The Double Spiral method is based on calculations of analytical functions on two contours, at each step, using the fast convolution. We illustrate the efficiency of the method computing the prices and sensitivities of Asians and barrier options with discrete monitoring, in exponential Lévy models. In the case of barrier options, an additional important ingredient are fractional-parabolic deformations of the contours of integration, with the sinh-acceleration. For Asians, calculations are reduced to multiplication by explicitly given functions, and the convolution operator with the kernel which enjoys properties similar to the properties of the kernel of the Hilbert transform. In the case under consideration. the kernel of this generalized Hilbert transform is expressed in terms of the Gamma function, and we use the nomer the Gamma transform.

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MS29

Option Pricing in Some Non-Lvy Jump Models

This paper considers pricing European options in a large class of one-dimensional Markovian jump processes known as subordinate diffusions, which are obtained by time changing a diffusion process with an independent Lvy or additive random clock. These jump processes are non-Lvy in general, and they can be viewed as natural generalization of many popular Lvy processes used in finance. Subordinate diffusions offer richer jump behavior than Lvy processes and they have found a variety of applications in financial modelling. The pricing problem for these processes presents unique challenges as existing numerical PIDE schemes fail to be efficient and the applicability of transform methods to many subordinate diffusions is unclear. We develop a novel method based on finite difference approximation of spatial derivatives and matrix eigendecomposition, and it can deal with diffusions that exhibit various types of boundary behavior. Since financial payoffs are typically not smooth, we apply a smoothing technique and use extrapolation to speed up convergence. We provide convergence and error analysis and perform various numerical experiments to show that the proposed method is fast and accurate.

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MS29

Additive Subordination and Its Applications in Finance

Applications in finance often require the use of time-inhomogeneous Markov processes. This paper studies additive subordination, which we show is a useful technique for constructing time-inhomogeneous Markov processes with analytical tractability. Additive subordination is the natural time-dependent generalization of the classical Bochner's subordination. We develop an analytical tractable formula for pricing crack spread options, as an application example.

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MS29

Long Forward Probabilities, Recovery and the Term Structure of Bond Risk Premiums

We show that the martingale component in the long-term factorization of the stochastic discount factor due to Alvarez and Jermann (2005) and Hansen and Scheinkman (2009) is highly volatile, produces a downward-sloping term structure of bond Sharpe ratios, and implies that the long bond is far from growth optimality. In contrast, the long forward probabilities forecast an upward sloping term structure of bond Sharpe ratios and implies that the long bond is growth optimal. Thus, transition independence and degeneracy of the martingale component are implau-

sible assumptions in the bond market.

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MS30

Machine Learning and Portfolio Optimization

We modify two popular methods in machine learning, regularization and cross-validation, for the portfolio optimization problem. First, we introduce performance-based regularization (PBR), where the idea is to constrain the sample variances of the estimated portfolio risk and return. The goal of PBR is to steer the solution towards one associated with less estimation error in the performance. We consider PBR for mean-variance and mean-CVaR portfolio optimization problems. For the mean-variance problem, PBR introduces a quartic polynomial constraint, from which we make two convex approximations; one based on rank-1 approximation and another based on the best convex quadratic approximation. For the mean-CVaR problem, the PBR model is a combinatorial optimization problem, but we prove its convex relaxation is tight. We establish asymptotic optimality of both SAA and PBR solutions, and show this extends to the corresponding efficient frontiers. We also develop a new, performance-based k-fold cross-validation algorithm for parameter calibration. Using this algorithm, we carry out an extensive empirical investigation and show PBR dominates all other benchmarks in the literature for two widely-used data sets with statistical significance.

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MS30

Data Driven Risk Management

The prevailing risk management approach in finance and insurance is to first estimate a parametric model from the market data and then determine the risk management strategy based on the estimated model. We propose a direct data driven approach to determine a risk management strategy. Computational results based on both synthetic data and real market data will be presented to illustrate the efficacy of the proposed method.

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MS30

Stock Portfolio Selection Using Learning-to-Rabk Algorithms with News Sentiment

Corporate textual risk disclosures as part of annual reports issued by U.S. public companies, mandated to the Securities and Exchange Commission (SEC), provide forward-looking information on their future business and potential risks. Using financial reports submitted to SEC from 2011 to 2014, we use variations of Latent Dirichlet Allocation (LDA) model to infer risk types and quantify the impact of different risk factors. We then investigate the impact of these risk factors on the companies stock prices across different industries.

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MS30

Efficient Machine Learning Method for Risk Management of Large Variable Annuity Portfolios

Variable annuity (VA) embedded guarantees have rapidly grown in popularity around the world in recent years. Valuation of VAs has been studied extensively in past decades. However, most of these studies focus on a single contract. These methods cannot be extended to valuate a large variable annuity portfolio due to the computational complexity. In this paper, we propose an efficient moment matching machine learning method to compute the annual dollar deltas, VaRs and CVaRs for a large variable annuity portfolio whose contracts are over a period of 25 years. There are two stages for our method. First, we select a small number of contracts and propose a moment matching Monte Carlo method based on the Johnson curve, rather than the well known nested simulations, to compute the annual dollar deltas, VaRs and CVaRs for each selected contract. Then, these computed results are used as a training set for well known machine learning methods, such as regression tree , neural network and so on. Afterwards, the annual dollar deltas, VaRs and CVaRs for the entire portfolio *are predicted* through the trained machine learning method. Compared to other existing methods, our method is very efficient and accurate, especially for the first 10 years from the initial time. Finally, our test results support our claims.

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MS31
Insider Trading with Residual Risk

We consider an extension of the Kyle (1985) model in which the insider is risk-averse and does not have complete information about the terminal value of the traded asset. The simultaneous addition of both risk aversion and residual risk changes the nature of equilibrium for both the market-maker and the insider: the market-maker is required to estimate the insider's inventory level in addition to the insider's private signal; the insider bases her trades on her present inventory level and the market-maker's estimation of her inventory level, in addition to the market-maker's valuation error. This induces a predictable component into the insider's trades despite her efforts to hide her strategy. We give conditions for the existence of linear equilibrium and investigate the effects of residual risk on the equilibrium behaviour.

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MS31
Optimal Market Making

Market makers provide liquidity to other market participants: they propose prices at which they stand ready to buy and sell a wide variety of assets. They face a complex optimization problem with both static and dynamic components. They need indeed to propose bid and offer/ask prices in an optimal way for making money out of the difference between these two prices (their bid-ask spread). Since they seldom buy and sell simultaneously, and therefore hold long or short inventories, they also need to mitigate the risk associated with price changes, and subsequently skew their quotes dynamically. In this talk, (i) I present a general modeling framework which generalizes (and reconciles) the various modeling approaches proposed in the literature since the publication of the seminal paper "High-frequency trading in a limit order book" by Avellaneda and Stoikov, (ii) I prove new general results on the existence and the characterization of optimal market making strategies, (iii) I obtain new closed-form approximations for the optimal quotes, (iv) I extend the modeling framework to the case of multi-asset market making, and (v) I show how the model can be used in practice in the specific (and original) case of two credit indices.

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MS31
Trading Foreign Exchange Triplets

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MS31
Portfolio Liquidity Estimation and Optimal Execution

Accurately estimating liquidity is an important ingredient in portfolio management. Traditionally, liquidity costs are estimated with single asset models. This ignores the fact that, fundamentally, liquidity is a portfolio problem since asset prices are correlated. We develop a model to estimate portfolio liquidity costs through a multi-dimensional generalization of the optimal execution model of Almgren and Chriss. Our model allows for the trading of standardized liquid bundles of assets (e.g., ETFs or indices). We show that the hedging benefits of trading with many assets significantly reduces cost when liquidating a large position. In a "large universe" asymptotic limit, where the correlations across a large number of assets arise from relatively few underlying common factors, the liquidity cost of a portfolio is essentially driven by its idiosyncratic risk. Moreover, the additional benefit of trading standardized bundles is roughly equivalent to increasing the liquidity of individual assets. Our method is tractable and can be easily calibrated from market data.

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MS32
Second-Best Tarification for a Producer-Provider of Electricity

Abstract Not Available At Time Of Publication.

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MS32
Model Uncertainty in Electricity Interconnector Markets

Abstract Not Available At Time Of Publication.

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MS32
Intra-Day Trading at the Epex

Abstract Not Available At Time Of Publication.

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MS32
Optimal Hedge Design

Abstract Not Available At Time Of Publication.

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MS33

Liability Concentration and Systemic Losses in Financial Networks

The objective of this study is to develop a majorization-based tool to compare financial networks with a focus on the implications of liability concentration. Specifically, we quantify liability concentration by applying the majorization order to the liability matrix that captures the interconnectedness of banks in a financial network. We develop notions of balancing and unbalancing networks to bring out the qualitatively different implications of liability concentration on the system's loss profile. We illustrate how to identify networks that are balancing or unbalancing, and make connections to interbank structures identified by empirical research, such as perfect and imperfect tiering schemes. An empirical analysis of the network formed by the banking sectors of eight representative European countries suggests that the system is either unbalancing or close to it, persistently over time. This empirical finding, along with the majorization results, supports regulatory policies aiming at limiting the size of gross exposures to individual counterparties.

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MS33

Bootstrap Percolation in Inhomogeneous, Directed Random Graphs and Financial Contagion

Bootstrap percolation is a process that is used to model the spread of an infection on a given graph. In the model considered each vertex is equipped with an individual threshold. As soon as the number of infected neighbors exceeds that threshold, the vertex gets infected as well and remains so forever. We perform a thorough analysis of bootstrap percolation on a novel model of directed and inhomogeneous random graphs, where the distribution of the edges is specified by assigning two distinct weights to each vertex, describing the tendency of it to receive edges from or to send edges to other vertices. Under the assumption that the limiting degree distribution of the graph is integrable we determine the typical fraction of infected vertices. Our model allows us to study settings that were outside the reach of current methods, in particular the prominent case in which the degree distribution has an unbounded variance. Among other results, we quantify the notion of "systemic risk", that is, to what extent local adverse shocks can propagate to large parts of the graph through a cascade, and discover novel features that make graphs prone/resilient to initially small infections. We show how our results can be used to study default contagion in a financial network. The talk will also provide an overview of the literature on bootstrap percolation and network models as related to systemic risk.

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MS33

Systemic Risk in Interbank Networks with Multiple Maturities

We consider the problem of systemic risk assessment in interbank networks in which interbank liabilities can have more than one maturity. In particular we allow for both short-term and long-term interbank liabilities. We develop a clearing mechanism for the interbank liabilities to deal with default of one or more market participants. Our approach generalises the clearing approach proposed by Eisenberg and Noe (2001) for the single maturity setting. We discuss novel effects that arise as soon as more than one maturity date is considered and discuss implications for systemic risk assessment.

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MS33

Systemic Risk in Inhomogeneous Financial Networks

To quantify and manage systemic risk in the interbank market, we propose a weighted, directed random network model. The vertices in the network are financial institutions and the weighted edges represent credit exposures between them. Our model resembles the strong degree of heterogeneity observed in empirical data and generalizes earlier work based on the configuration model to inhomogeneous random graphs with unbounded variance of the degree sequence. To study the networks resilience to local shocks (only a few initially defaulted institutions) we relate the exposure based model to a threshold model and derive asymptotic results for default contagion. Based on some network parameters, our results allow to determine the fraction of defaulted institutions at the end of a contagion process and to characterize resilient and non-resilient cases. For networks with degree sequence without second moment, a small number of initially defaulted institutions can trigger a substantial default cascade. Our results are in stark contrast to earlier findings derived under a second moment assumption. Furthermore, we determine minimal capital requirements sufficient to make the network resilient to small shocks. The capital requirements are robust with respect to a miss-specification of the dependency structure of in- and out-degrees in the network.

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MS34

Leverage, Market Liquidity, and Financial Fragility

We present a model of an economy with financial frictions such as market liquidity and leverage constraints. The economy can develop endogenous instability and occasionally enters volatile crisis episodes, in which risk premium of assets increases suddenly and dramatically. Our model show that leverage regulation has a significant impact on how frequent the crises will occur. This is a joint work with Nan Chen and Xuedong He.

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MS34

On the Measurement of Economic Tail Risk

This paper attempts to provide a decision-theoretic foundation for the measurement of economic tail risk, which is not only closely related to utility theory but also relevant to statistical model uncertainty. The main result is that the only risk measures that satisfy a set of economic axioms for the Choquet expected utility and the statistical property of generalized elicitability (i.e. there exists an objective function such that minimizing the expected objective function yields the risk measure) are the mean functional and Value-at-Risk (VaR), in particular the median shortfall, which is the median of tail loss distribution and is also the VaR at a higher confidence level. We also discuss various approaches of backtesting and their relations to elicitability and co-elicitability. In addition, we extend the result to address model uncertainty by incorporating multiple scenarios. As an application, we argue that median shortfall is a better alternative than expected shortfall for setting capital requirements in Basel Accords. This is a joint work with Steven Kou.

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MS34

Risk Managing FVA

Funding valuation adjustment (FVA) has been a central issue in financial markets for years. There exist different and even opposing views on the definition and adoption of FVA from the viewpoints of pricing, booking or accounting. In this talk, we work under a framework of replication pricing and redefine, intuitively, FVA as well as CVA (i.e., credit valuation adjustment). With our formulations, we draw a boundary between FVA and DVA (i.e., debit valuation adjustment). From the viewpoints of pricing and accounting, we argue against the booking of FVA for derivative trades, echoing Hull and White (2013). And we argue for the adoption of VaR measure for funding risks.

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MS34

Diversification of Portfolio Tail Risk

We develop explicit and accurate asymptotic expansions of the portfolio VaR and Expected Shortfall (ES) for a large family of multivariate elliptical distributions. We show that while the tail heaviness of joint asset return distribution dictates how much larger portfolio ES is comparing to VaR, it is the dependence structure that determines the diversification benefits when portfolios are merged together for joint margining.

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MS35

Predictable Forward Investment Preferences

We introduce a new class of investment preferences, called Predictable Forward Investment Preferences (PFIP). These preference are discrete-in-time and are motivated by the so-called Forward Investment Preferences (FIP) introduced by Musiela and Zariphopoulou, in the sense that the risk preferences are stochastic and updated forward in time as the market unfolds. In a binomial market setting, we establish the existence of PFIP through an explicit construction. Namely, we show that in the interval between two subsequent updates of the forward preferences, the investor solves a (conditional) inverse Merton investment problem. We reduce this inverse problem to an iterative (i.e. single variable) functional equation and provide existence and uniqueness conditions for its solution. This functional equation is the counterpart of the stochastic partial differential equation that characterizes FIP.

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MS35

An Ergodic BSDE Approach to Entropic Risk Measures and their Large Time Behavior

In this talk, I will first discuss the long-term behavior of the entropic risk measures in a stochastic factor model, under both the forward performance and the classical utility frameworks. I will show that they both converge to a constant, which is independent of the initial state of the stochastic factors. Using ergodic BSDE, I will then discuss their convergence rate. I will also present a parity result between the two measures (forward and traditional). (joint work with W. F. Chong, Y. Hu, and T. Zariphopoulou).

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MS35

Filtrations and Investment

Intuitively, filtrations (information) should play an important role in investment, for a better 'informed' portfolio manager should, in principle, make, better investment decisions than the one that is less 'informed'. One would also

think that there should be a minimal information a portfolio manager should use. However, portfolio managers may use various other sources (analysts recommendations for stocks, sector specific 'non-tradable' information, market indexes, GDP growth, etc.). In a more mathematical literature, where portfolio is an output of utility maximization over a universe of stocks, different model specifications may lead to analysis within the so called complete or incomplete models. While this concept is critical for valuations of derivative products, its importance in investment is less clear. Indeed, one may imagine situations in which the minimal price based filtration may give rise to both, complete and incomplete models. In this talk, we analyze the case with two sources of information based on which decisions are made, and we discuss various features of the investment criteria and the optimal portfolios.

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MS35

Dynamic Utilities for Time Inconsistent Problems

Time inconsistency is well known in economics. There are typically two approaches, which lead to different values: the strategy of consistent planning and the strategy of precommitment. The former one is itself time consistent, and the latter one is a static problem. We notice that the latter is time inconsistent when people use the same "utility" along the time, and we propose to find some dynamic utility, which (i) makes the problem time consistent and (ii) maintains the same value as the original static problem. We will also compare our dynamic utility with the forward utility of Musiela-Zariphopoulou. The talk is based on a joint work with Karnam and Ma.

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MS36

Theoretical and Numerical Analysis of Local Stochastic Volatility Models

The calibration on to the vanilla market of general stochastic volatility models has led to what is now known as Local Stochastic Volatility (LSV) models. In this context, various techniques have been used in order to numerically perform the calibration of such models. In my talk, I will address the theoretical foundations, as well as the numerical analysis, of LSV models, pointing out the inherent theoretical and related pratical difficulties, in connection with general McKean-Vlasov equations.

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MS36

The Local Stochastic Volatility Puzzle, or How to Relieve a Hangover

Local stochastic volatility models are remarkable because they tend to agree on first generation exotic prices irrespective of the underlying stochastic volatility process. In this talk we discuss the importance of this empirical fact in exotics trading, and provide some understanding of why it is so.

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MS36

The Particle Method for Smile Calibration and Its Application to Stochastic Local Volatility Models

Calibration of models to market smiles is a crucial issue for risk management in finance. This used to be done by running time-consuming optimization routines. In this talk we will show how particle methods very efficiently solve a wide variety of smile calibration problems, without resorting to any optimization: calibration of stochastic local volatility models (our main focus in this talk), possibly with stochastic rates and stochastic dividends; calibration of the local volatility model with stochastic rates; calibration to a basket smile of multi-asset local volatility-local correlation models; calibration of path-dependent volatility models and path-dependent correlation models; calibration of cross-dependent volatility models. The particle method is a Monte Carlo method where the simulated asset paths interact with each other so as to ensure that a given market smile (or several of them) is fitted. PDE methods typically do not work for these high-dimensional models. The particle method is not only the first available exact simulation-based method for smile calibration. It is also robust, easy to implement, and fast. Icing on the cake: there are nice mathematics behind the scenes, namely the theory of McKean SDEs, the propagation of chaos, and a new Malliavin disintegration by parts formula. Some crucial mathematical questions, such as the existence and uniqueness of the McKean SDEs that arise in these smile calibration problems, are still open problems.

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MS36

Stochastic Local Volatility Models for Foreign Exchange Markets: A Practitioners View

Foreign Exchange Markets are characterized by very specific vanilla market conventions and dynamics and a unique set of liquidly traded exotics. These features gave rise to the first published Stochastic Local Volatility models in the late 1990s. FX market practitioners have adopted these models as standard for pricing and risk managing their exotic portfolios. The focus of the talk will be to examine the types of LSV models that can be used to calibrate these instruments and explore the sensitivity of exotic option prices to various model features. The talk will also examine empirical smile dynamics and compare with model predictions.

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MS37

Optimal Deleveraging under Cross-Asset Price Pressure

We study an optimal portfolio deleveraging problem, where the objective is to meet specified debt/equity requirements

at the minimal execution cost. During the course of trading, we account for permanent and temporary price impact, as well as the cross-asset price pressure which measures the impact on an asset caused by the trading of other assets. Mathematically, the optimal deleveraging problem is formulated as a non-convex and non-separable quadratic program with quadratic and box constraints. We develop successive convex optimization algorithms to obtain the optimal deleveraging strategy.

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MS37

A Simulation Method for Stochastic Dynamic Programming with Applications in Algorithmic Trading

We use the information relaxation technique to develop a value-and-policy iterative method to solve stochastic control problems. Each iteration generates an upper bound, a suboptimal policy and its corresponding value. The gap between the upper and lower bounds can help us to access the quality of the suboptimal policy. We show that the sequences of bounds converge to the optimal value within finite number of iterations. A regression-based Monte Carlo algorithm is developed to implement this method. As a numerical illustration, we apply it to the classical optimal order execution problems.

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MS37

Optimal Order Exposure in a Limit Order Book

Hidden orders are offered by many lit venues for participants to hide the true size of their orders. We propose a multi-stage dynamic programming model to determine the optimal choice of limit and hidden orders in a limit order market. We obtain analytical solutions for this model under certain assumptions. We use order-message data from NASDAQ to estimate the model and demonstrate the generality of our assumptions. Our analytical solutions together with numerical experiments suggest that participants should submit hidden orders at early stages, possibly turn to a mixture of limit and hidden orders later, and use limit orders only when the deadline is approaching. This is a joint work with Yuanyuan Chen and Duan Li.

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MS38

ADI Schemes for the Valuation of Multi-Asset American-Style Options

We consider the numerical valuation of American-style options by the recently proposed class of ADI-IT schemes (Haentjens & In 't Hout, 2015). ADI-IT schemes are applied to the pertinent multidimensional partial differential complementarity problems (PDCPs) and effectively combine Alternating Direction Implicit (ADI) schemes for partial differential equations with the Ikonen-Toivanen (IT) splitting method for complementarity problems. In this talk we report on our recent progress on the theory and application of this class of numerical schemes. In particular, we compare their efficiency to other contemporary methods for valuing American-style options via PDCPs such as the penalty approach.

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MS38

New Fully Implicit Hv Finite-Difference Scheme Combined with the Method of Pseudo-Differential Operator for Pricing Lsv Models with Stochastic Interest Rates and Correlated Jumps

Pricing and hedging exotic options using local stochastic volatility models drew a serious attention within the last decade, and nowadays became almost a standard approach to this problem. In this paper we show how this framework could be extended by adding to the model stochastic interest rates and correlated jumps in all three components. We also propose a new fully implicit modification of the popular Hundsdorfer and Verwer and Modified Craig-Sneyd finite-difference schemes which provides second order approximation in space and time, is unconditionally stable and preserves positivity of the solution, while still has a linear complexity in the number of grid nodes.

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MS38

Pricing American Options under Multi-State Regime Switching with Jumps

An efficient second-order method based on exponential time differencing approach for solving American options under multi-state regime switching with jumps is developed and analyzed for stability and convergence. The method is seen to be strongly stable (L-stable) in each regime which avoids any spurious oscillations caused by non-smooth initial data. The implicit predictorcorrector nature of the method makes it highly efficient in solving nonlinear systems of partial differential integral equations arising from multi-state regime switching model with jumps. A general framework for multi-state regime switching with jumps in multi-asset American option has been provided. Numerical experiments are performed on two assets to demonstrate the performance of the method with convex as well as non-convex payoffs and is found to be efficient, stable and reliable

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MS38

ADI Finite Difference Schemes for the Calibration

of Stochastic Local Volatility Models

In contemporary financial mathematics, stochastic local volatility (SLV) models form state-of-the-art models to describe asset price processes. The local component of the SLV model, the so-called leverage function, is defined in a natural way such that the SLV model yields the same fair value for vanilla options as the underlying local volatility (LV) model. Determining this leverage function is, however, a highly non-trivial task. For example, the fair option values defined by the LV model can often not be obtained analytically and have to be approximated, e.g. by numerically solving the corresponding backward PDE. Consider any given discretization by finite differences of the one-dimensional backward PDE from the LV model and suppose discretization of the two-dimensional backward PDE corresponding with the SLV model is performed by similar finite difference formulas. In this talk we shall propose a calibration technique with the useful property that it determines the leverage function such that both discretizations define exactly the same approximation for the fair value of vanilla options. In this calibration procedure, which involves a two-dimensional PDE problem, alternating direction implicit (ADI) time stepping schemes are used as they are highly efficient in comparison to classical implicit methods. Ample numerical experiments are provided that illustrate the effectiveness of this calibration procedure.

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MS38

Option Pricing under the Cgmy-Process

We price options when the underlying asset follows a CGMY-process. To that end, we derive the Kolmogorov forward fractional partial differential equation (FPDE) for this process. We obtain the option price by integrating the resulting probability density function multiplied by the pay-off function. Hence, we only have to solve one FPDE to price several options. This is useful in practical applications where it is common to price many options simultaneously for the same underlying process. Numerical results will be presented that demonstrates the usefulness of the proposed method.

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MS39

Optimal Investment under Funding Risk

This paper explores a one-period model for a firm that finances its operations through debt provided by heterogeneous creditors. Creditors differ in their beliefs about the firm's investment outcomes. We show the existence of Stackelberg equilibria in which the firm holds cash reserves in order to provide incentives for pessimistic creditors to invest in the firm. We find interest rates and cash holdings to be complementary tools for increasing debt capacity. In markets with a high concentration of capital across a small interval of pessimistic creditors or by a few large creditors, cash holdings is the preferred tool to increase the debt capacity of the firm.

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MS39

Dynamic Prudential Regulation

We analyze the design and impact of bank regulation using a dynamic structural framework. The optimal regulatory policy combines a target capital requirement, the mitigation of underinvestment, an intervention capital requirement to control inefficient risk-taking, and recapitalization of distressed banks. The optimal target and intervention capital requirements are consistent with the substantially higher capital requirements proposed in the Basel III agreement, and together achieve most of the benefits of regulation by alleviating underinvestment and asset substitution. They are interdependent and respond in different ways to banks asset characteristics, suggesting that regulatory policies should be carefully tuned to the economic environment.

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MS39

Risk-Based Capital Requirements and Optimal Liquidation in a Stress Scenario

We develop a simple yet realistic framework to analyze the impact of an exogenous shock on a bank's balance-sheet and its optimal response when it is constrained to maintain its risk-based capital ratio above a regulatory threshold. We show that in a stress scenario, capital requirements may force the bank to shrink the size of its assets and we exhibit the bank's optimal strategy as a function of regulatory risk-weights, asset market liquidity and shock size. When financial markets are perfectly competitive, we show that the bank is always able to restore its capital ratio above the required one. However, for banks constrained to sell their loans at a discount and/or with a positive price impact when selling their marketable assets (large banks) we exhibit situations in which the deleveraging process generates a death spiral. We then show how to calibrate our model using annual reports of banks and study in detail the case of the French bank BNP Paribas. Finally, we suggest how our simple framework can be used to design a systemic capital surcharge.

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MS39

Optimal Execution of Limit and Market Orders with Trade Director, Speed Limiter, and Fill Uncertainty

We study the optimal execution of market and limit orders with permanent and temporary price impacts under con-

tinuous time. Our model also features uncertainty in the filling of limit orders, a trade speed limiter, and a trader director. We formulate an optimal stochastic control problem to determine the dynamic execution strategy, with a quadratic terminal penalty to ensure complete liquidation. For comparison, we also solve the schedule-following optimal execution problem that penalizes deviations from an order schedule. Numerical results are provided to illustrate the optimal market and limit orders over time. Our model is able to encourage non-negativity of the trading rates. In addition, we identify conditions on the model parameters to ensure optimality of the controls and boundedness of the associated stochastic control problem.

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MS40

Healthcare and Consumption with Aging

Healthcare benefits individuals by slowing the natural growth of mortality, indirectly increasing utility through consumption over a longer lifetime. This paper solves the problem of household dynamic healthcare, consumption, and saving when natural mortality grows exponentially to reflect the Gompertz law, while both utility and healthcare are isoelastic. The optimization problem reduces to a nonlinear ordinary differential equation with a unique solution, which has an explicit expression in the old-age limit. Optimal consumption and healthcare spending policies depend on mortality and imply an endogenous curve similar to the Gompertz law. Absolute health expenditure increases with age; relative to consumption, it increase for the typical adult life and slowly declines in the old age.

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MS40

Closed-Loop Strategies in Stochastic Linear-Quadratic Differential Games

For two-person differential games, it is understood that open-loop controls are not non- anticipating and therefore, they are not practically useful. Naturally, both players should take closed-loop strategies which are non-anticipating and with that, the players are treated symmetrically. Mathematically, how one can distinguish the essential difference between open-loop and closed-loop strategies? In this talk, we will survey our recent works on this issue for linear-quadratic optimal controls, two-person zero-sum differential games and two-person nonzero-sum differential games.

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MS40

Optimal Dividend Strategies of Two Collaborating Businesses with Transaction Costs

We consider the optimal dividend payment strategy for an insurance company, having two collaborating business lines, where their surplus processes are modeled by diffusion processes and the dividends paid by different business lines are weighted differently. We find the optimal dividend strategy when money is transferred between two business lines without transaction costs. We show the optimal value function is a continuous viscosity solution to the corresponding HJB equation when money is transferred with transaction costs. We also prove a verification theorem. Finally, we find the optimal solution to the problem with transaction costs in the symmetric case.

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MS40

Continuous Inventory Models of Diffusion Type: Long-Term Average Cost Criterion

This work examines a control problem when, in the absence of ordering, the single-item inventory process has continuous sample paths. The inventory process is modeled by a one- dimensional diffusion on some interval in which the left boundary is attracting, so as to capture the effect that demand tends to decrease the inventory level, and the right boundary is non-attracting. Orders instantaneously increase the inventory level and incur both positive fixed and level dependent costs. In addition, state-dependent holding/backorder costs are incurred continuously. The managers influence on the inventory is limited solely to ordering policies that increase the current level. The objective of the manager is to find an ordering policy that minimizes the long-term average holding/backorder and ordering cost. This work provides minimal conditions on the model which imply that an optimal ordering policy exists in the class of (s,S)-ordering policies. Examination of the steady state behavior of (s,S) policies leads to a two-dimensional nonlinear optimization problem for which a pair of optimizers establishes the levels for an optimal (s,S) policy. This works contribution is a set of very mild sufficient conditions for the existence of an optimal (s, S)-ordering policy.

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MS41

Long Memory and Roughness in Stochastic Volatility Models

Long memory stochastic volatility (LMSV) models have been used to explain the persistence of volatility in the market, while rough stochastic volatility (RSV) models have been shown to reproduce statistical properties of low frequency financial data. In these two classes of models, the volatility process is often described by a fractional Ornstein-Uhlenbeck process with Hurst parameter H $\in$ (0,1), where H>1/2 for LMSV models and H<1/2 for RSV models. The goal of this talk is to review these models and discuss ways to estimate their parameters for all values of H. An application using S&P 500 data is also discussed.

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MS41

Gaussian and Self-similar Stochastic Volatility Models

The results discussed in the talk are joint with F. Viens and X. Zhang (Purdue University). The talk is devoted to uncorrelated Gaussian stochastic volatility models. The volatility of an asset in such a model is described by the absolute value of a Gaussian process. We find sharp asymptotic formulas with error estimates for the realized volatility and the asset price density in a general Gaussian model, and also characterize the wing behavior of the implied volatility. For Gaussian models with self-similar volatility processes, we obtain sharp asymptotic formulas describing the small-time behavior of the asset price density, the call pricing function, and the implied volatility. The parameters appearing in the asymptotic formulas mentioned above are expressed in terms of the Karhunen-Loeve characteristics of the volatility process. We will discuss numerous examples of Gaussian and self-similar stochastic volatility models, and show how to recover the self-similarity index knowing the small-time behavior of the call pricing function or the implied volatility.

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MS41

Fractional Stochastic Volatility

Empirical studies show that the volatility may exhibit correlations that decay as a fractional power of the time offset. We present an analysis for the case when the stationary stochastic volatility model is constructed in terms of a fractional Ornstein Uhlenbeck process to have such correlations. It is shown how the associated implied volatility has a term structure that is a function of maturity to a fractional power.

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MS41

Bayesian Modeling of High-Frequency Crude Oil Prices

We propose a new class of stochastic volatility models for around-the-clock 5-minute returns on crude oil prices. Our models incorporate the following key features: multiple persistent stochastic volatility factors, jumps in prices and volatilities, seasonal components capturing time of the day patterns, correlations between return and volatility shocks, and announcement effects. We develop an integrated MCMC approach to estimate interday and intraday parameters and states using high-frequency data without resorting to various aggregation measures like realized volatility. We provide a case study using data from 2008 to 2015, and use particle filters to construct likelihood functions for model comparison and out-of-sample forecasting. We show that our approach improves realized volatility forecasts over existing benchmarks including intraday GARCH models and realized volatility models.

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PP1

Weakly Chained Matrices, Policy Iteration, and Impulse Control

This work is motivated by numerical solutions to Hamilton-Jacobi-Bellman quasivariational inequalities (HJBQVIs) associated with combined stochastic and impulse control problems. A direct control scheme for such an HJBQVI takes the form of a Bellman problem (BP) involving an operator which is not necessarily contractive. We consider the well-posedness of the BP and give sufficient conditions for convergence of a policy iteration to its unique solution. In the event that these conditions do not hold, weaker conditions guarantee uniqueness, from which it is possible to salvage the convergence of policy iteration by (roughly speaking) pruning policies that render the operator appearing in the BP singular. These results are established using weakly chained diagonally dominant matrices, which give a graph-theoretic characterization of weakly diagonally dominant M-matrices. The BP also happens to be the dynamic programming equation associated with an infinite-horizon Markov decision process with vanishing discount factor (a

generalization of reflecting boundaries), which is of independent interest.

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PP1

Portfolio Analysis by Graph Similarity Function

We have to rebalance our portfolio consistently to stay in the market.The rebalancing is done in the way that the portfolio is diversified.We can handle the unsystematic risk of the classes and stocks in it by controlling the quantified factors affecting the risk.Once the factors are quantified,we can handle all other stocks which depend on these factors. The major work is on quantifying the dependency of stocks in a portfolio by representing them in graph form and calculating the similarity between them.The threshold value is calculated using euclidean measure and the nodes exceeding this can be discarded. This is the efficient way to handle diversified portfolio with large number of stocks.

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PP1

Impact of Contingent Payments on Systemic Risks in Financial Networks

We develop an extension of the Eisenberg-Noe network model for the financial system to incorporate obligations dependent on the state of the system. This model allows for the inclusion of insurance payments and financial derivatives into the Eisenberg-Noe model. We look at the sufficient conditions for existence and uniqueness of clearing payments and prices in cases with no illiquid asset, a single illiquid asset and multiple illiquid assets. In the case of multiple illiquid assets, we also prove sufficient conditions for the existence of a game-theoretic liquidation strategy with corresponding clearing payments and liquidation prices. Furthermore we also study the dependence of clearing payments and prices on system parameters such as cash flow.

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PP1

A New Finite Difference Method for Pricing and Hedging Fixed Income Derivatives: Comparative Analysis and the Case of An Asian Option

We propose a second order accurate numerical finite difference method to replace the classical schemes used to solve PDEs in financial engineering. We name it Modified Fully Implicit method. The motivation for doing so stems from the accuracy loss while trying to stabilize the solution via the up-wind scheme in the convective term as well as the fact that spurious oscillations solutions occur when volatilities are low (this is actually the range that is commonly observed in interest rate markets). Unlike the classical schemes, our method covers the whole spectrum of volatilities in the interest rate dynamics. We obtain analytical and numerical results for pricing and hedging a zero-coupon bond and an Asian interest rate option. In the case of the Asian option, we compare the realistic discrete compounding interest rate scheme (associated with the Modified Fully Implicit method) with the continuous compounding scheme (often exploited in the literature), obtaining relative discrepancies between prices exceeding 50%. This indicates that the former scheme is more appropriate then the latter to price more complicate derivatives than straight bonds.

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PP1

Quantization Meets Fourier: A New Approach for Pricing with Stochastic Volatility

Quantization is a tool used in numerical probability, and it consists in finding a grid that minimize in an L^2 sense the distance between the original random variable and a discrete version of it, finding the minimum of a distance function. Quantization in option pricing has become more interesting with the introduction of the new recursive marginal quantization technique, widely studied for local volatility models, and stochastic volatility models.
In this paper we present a completely new approach: using some Fourier techniques, we obtain the density of the price process from the characteristic function of the model. We consider the price process at maturity as a random variable, and, having computed his density, we quantize it using a Newton Raphson algorithm.
As numerical examples we consider a large family of stochastic volatility models, both affine and non affine. We apply our methodology to the pricing of European options, and we compare it with the alternative Fourier techniques. The quantization based method reveals to be very efficient, to the point that it is possible to calibrate different models. We show also how to deal with non vanilla options, providing some numerical examples for the pricing of American options. This approach is a valid alternative to the Least Square MC method.
In conclusion our framework is flexible enough to price European options, calibrate the market, approximate transition densities and price path dependent options.

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PP1

Hybrid Finite Difference / Pseudospectral Methods for Stochastic Volatility Models

In this work we propose a hybrid finite difference / pseudospectral scheme for option pricing problems under stochastic volatility models. As testbeds for two and three factor models we consider the Heston and Heston-Hull-White partial differential equation. The method exploits

the anisotropic smoothness of the underlying problem to achieve spectral accuracy in the smooth coordinate direction. In the non-smooth direction we consider a second order as well as a high-order-compact discretization.

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PP1

Saddlepoint Methods for Risk Sensitivities and Markovian Projection

We derive new saddlepoint expansions for conditional expectations in the form of $E[X|Y = a]$ and $E[X|Y = a]$ for the sample mean of a continuous random vector (X, Y) whose joint moment generating function is available. The newly developed expansions provide fast and accurate analytic solutions for the sensitivities of risk measures such as valueat-risk and conditional value-at-risk. In addition, we also consider the Markovian projection approach to price European basket options. The difficulty lies in the explicit computation of the local volatility function represented in the form of $E[X|Y = a]$. We successfully apply the newly developed expansions to compute the local volatility function. Numerical results will verify the accuracy of the new approximations.

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PP1

Optimal Pairs Trading with Time-Varying Volatility

We propose a pairs trading model that incorporates a time-varying volatility of the Constant Elasticity of Variance type. Our approach is based on stochastic control techniques; given a fixed time horizon and a portfolio of two co-integrated assets, we define the trading strategies as the portfolio weights maximizing the expected power utility from terminal wealth. We compute the optimal pairs strategies by using a Finite Difference method. Finally, we illustrate our results by conducting tests on historical market data at daily frequency. The parameters are estimated by the Generalized method of moments.

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PP1

Radial Basis Function Generated Finite Differences for Basket Option Pricing

Pricing financial derivatives is a crucial process for reliable trading, investment strategy development and calibration of financial models. Many of such contracts are issued on a multitude of underlying assets where consequently their pricing leads to complex high-dimensional problems, often requiring advanced high-performance numerical treatment in order to be solved. Therefore, a mesh-free and sparse numerical method known as radial basis function generated finite differences (RBF-FD) is presented as an efficient way to tackle basket options. The method is a mesh-free generalization of classical finite differences, derived as a localized version of radial basis function approximation, and as such is exploiting the best properties from both of the approaches. We will present numerical experiments demonstrating the usefulness of our proposed method.

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PP1

Path-differentiability of BSDE Driven by a Continuous Martingale

We study existence, uniqueness, and path-differentiability of solution for backward stochastic differential equation (BSDE) driven by a continuous martingale M with $[M, M]_t = \int_0^t m_s m_s^* d\mathrm{tr}[M, M]_s$: $Y_t = \xi(M_{[0,T]}) + \int_t^T f(s, M_{[0,s]}, Y_{s-}, Z_s m_s) d\mathrm{tr}[M, M]_s - \int_t^T Z_s dM_s - N_T + N_t$. Here, for $t \in [0, T]$, $M_{[0,t]}$ is the path of M from 0 to t, and $\xi(\gamma_{[0,T]})$ and $f(t, \gamma_{[0,t]}, y, z)$ are deterministic functions of $(t, \gamma, y, z) \in [0, T] \times D \times \mathbb{R}^d \times \mathbb{R}^{d\times n}$. The path-derivative is defined as a directional derivative with respect to the path-perturbation of M in a similar way to the vertical functional derivative introduced by Dupire (2009), and Cont and Fournie (2013). We first prove the existence, uniqueness, and path-differentiability of solution in the case where $f(t, \gamma_{[0,t]}, y, z)$ is Lipschitz in y and z. After proving Z is a path-derivative of Y, we extend the results to locally Lipschitz f. When the BSDE is one-dimensional, we could show the existence and uniqueness of solution. On the contrary, when the BSDE is multidimensional, we show existence and uniqueness only when $[M, M]_T$ is small enough: otherwise, we provide a counterexample that has blowing-up solution. Lastly, we investigate the applications to utility maximization problems under power and exponential utility function.

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PP1

Optimal Order Execution Across Multi-Platform

In this study, we consider the problem of the optimal splitting of a large order across multiple trading venues. A trader has access to a wide variety of alternative destinations to send each piece of her large order. Conventional optimal trade execution models focus on minimizing the trading impact by splitting a large order into smaller chunks spread in time. Order placement problem finds the optimal decision on the order size and the destination in time. Limit order flow can be viewed as Multivariate versions of the Poisson process with independent increments and Markov property. These properties are used to characterize optimal order execution problem and formulate in a stochastic control framework. Finally, the performance of the algorithm is investigated on simulated data associated with heterogeneity in trading venues.

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PP1

An Efficient Meshfree Approach to Pricing Financial Contracts

Nowadays, financial contracts become more and more complex, hence pricing of such contracts requires more and more computational effort. Furthermore, standard grid methods demand high memory capacity even for moderately low problem dimensions. A way to overcome this issue is to use spectral methods such as radial basis function (RBF) methods. Thanks to their high order convergence properties the problem with fitting data into a limited memory volume can be resolved. However, the linear system that arises after the discretization and is needed to be solved has a dense structure. In order to sparsify the problem localization techniques, such as partition of unity, can be applied. This allows to increase the computational efficiency as well as to reduce the memory load even more. Thus, such localized RBF methods become an attractive option for pricing complex financial instruments. We support this statement by presenting numerical results for different types of derivative contracts. The results confirm the advantage of RBF methods especially for higher dimensional problems.

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PP1

Quanto Pricing in Stochastic Correlation Models

Correlation plays an important role in pricing multi-asset option, in this work we incorporate a stochastic correlation into pricing Quanto option which is one special and important type of multi-asset option. Motivated by the market observations that the correlations between financial quantities behave like a stochastic process, instead of using a constant correlation, we allow the asset price process and the exchange rate process to be stochastically correlated with stochastic correlation driven by the Ornstein-Uhlenbeck process and the bounded Jacobi process, respectively. We derive an exact Quanto option pricing formula in the stochastic correlation model of the Ornstein-Uhlenbeck process and a highly accurate approximated pricing formula in the stochastic correlation model of the bounded Jacobi process, where correlation risk has been hedged. The comparison between prices using our pricing formula and the Monte Carlo method are provided. We show that the exogenously incorporated stochastic correlation has an improvement in generating Quanto implied volatility, although keeping constant volatilities for the underlying asset and the exchange rate.

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PP1

Controlled Markov Decision Processes with AVaR Criteria for Unbounded Costs

In this paper, we consider the control problem with the Average-Value-at- Risk (AVaR) criteria of the possibly unbounded L1-costs in infinite horizon on a Markov Decision Process (MDP). With a suitable state aggregation and by choosing a priori a global variable s heuristically, we show that there exist optimal policies for the infinite horizon problem for possibly unbounded costs.

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PP1

Term Structure of Default Swap Rates for a Legal Entity with Perpetual Debt and Jumpy Assets

This paper aims at exploring the term structure of credit default swap rates. We employ a structural model for a firm with perpetual debt and a Levy process for the assets. We value finite tenor credit default swaps under an equivalent martingale measure. In particular, we show that short tenor swap rates can be significantly positive due to a non-zero Levy density. Furthermore, application to market data is discussed.

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PP1

Optimal Liquidation Strategy Across Multiple Exchanges under a Jump-Diffusion Fast Mean-Reverting Model

The appearance of new trading destinations facilitates trading the same financial instrument si- multaneously in different venues. To execute a large order, market participants may need to make decisions about how to split the order across multiple venues and at what prices to post the limit orders during the trading horizon to control the overall tradeoff between market impact and market risk. The decisions are in uenced by traders' risk aversions and the micro-structural market impact. We adopt a similar quantitative model framework as in Avellaneda and Stoikov (2008) [5] to study the optimal liquidation problem with limit and market orders across multiple venues. A two-point jump-diffusion model with fast mean-reverting stochastic volatility is employed to describe the dy- namics of the underlying stock price. In the case of a single trading venue, we derive an optimal split between market and limit orders as well as the optimal quoting strategy for the orders posted to the limit order book. For the general case of multiple exchanges, we derive an optimal order allocation strategy characterized by different rebate rates, execution risks and micro-structural features.

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PP1

On Construction of Smooth Market in Models with Transaction Costs

Transaction costs play a significant role in financial market. One of the reason is that transaction costs give one security two different prices; i.e., bid price and ask price. This phenomenon, like a deviation from low of one price, makes difficult to analyse models with transaction costs. To tackle this difficulty, two research approaches have been conducted: One is to rigorously derive the optimal trading strategy for investors in market with transaction costs. Second is to construct the market microstructure model where market maker chooses the optimal bid-ask spread which maximizes her profit. We consider simultaneous optimization of investors and the market maker and analyse impact of their preferences on the transaction in market with transaction costs.

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