IMS-FIPS 2015 Abstracts
Rutgers University, New Brunswick, New Jersey
June 25 – June 27
www.fsrm.rutgers.edu/fips2015

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**Plenary I**  
**Chair: Rong Chen**

**Diffusion scaling of a limit-order book model**  
Steven E. Shreve, Orion Hoch and University Professor, Department of Mathematical Sciences, Carnegie Mellon University

With the movement of trading away from the trading floor onto electronic exchanges - and the accompanying rise in the volume of order submission - has come an increase in the need for tractable mathematical models of the whole limit order book. The problem is inherently high-dimensional and the most natural description of the dynamics of the order flows has them depend on the state of the book in a discontinuous way. We examine a popular discrete model from the literature and describe its limit under a diffusion scaling inspired by queueing theory. Interesting features include a process that is either "frozen" or diffusing according to whether another diffusion is positive or negative. This is joint work with Christopher Almost, John Lehoczky, and Xiaofeng Yu.

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**Plenary II**  
**Chair: Lauren Hannah**

**Big n, Big p: Eigenvalues for Cov Matrices of Heavy-Tailed Multivariate Time Series**  
Richard Davis, Columbia University

In this paper we give an asymptotic theory for the eigenvalues of the sample covariance matrix of a multivariate time series when the number of components $p$ goes to infinity with the sample size. The time series constitutes a linear process across time and between components. The input noise of the linear process has regularly varying tails with index between 0 and 4; in particular, the time series has infinite fourth moment. We derive the limiting behavior for the largest eigenvalues of the sample covariance matrix and show point process convergence of the normalized eigenvalues as $n$ and $p$ go to infinity. The limiting process has an explicit form involving points of a Poisson process and eigenvalues of a non-negative definite matrix. Based on this convergence we derive limit theory for a host of other continuous functional of the eigenvalues, including the joint convergence of the largest eigenvalues, the joint convergence of the largest eigenvalue and the trace of the sample covariance matrix, and the ratio of the largest eigenvalue to their sum. In addition, we apply the limit theory in the setting of a paper by Lam and Yao (2012, AoS) who suggested a tool for determining a number of relevant eigenvalues in the context of high-dimensional financial time series analysis. (This is joint work with Thomas Mikosch and Johann Heiny at the University of Copenhagen.)
Plenary III  
Chair: Neville O’Reilly  
Combining Information from Stock and Option Prices: An Empirical Likelihood Approach  
Zhiliang Ying, Columbia University

It has long been recognized that option prices contain information about the dynamics of the underlying asset returns. In this talk, we show that the option information could lead to sharper estimation of the returns dynamics (e.g. drift, volatility and jump parameters) and more efficient ways to reflect current market condition, which is especially useful during financial crises. Our approach is through developing an empirical likelihood based method that can combine the return series and the associated derivative prices for the purpose of estimation. We apply the new method to Standard and Poor’s 500 Index and its derivative prices. Our empirical findings suggest that inclusion of option price data provides a more seasonable set of estimates that can reflect the market conditions. We also provide theoretical justification via deriving large sample properties. This is joint work with Steven Kou (NUS) and Tony Sit (CUHK).

Plenary IV  
Chair: Lee Dicker  
Fracking, Renewables & Mean Field Games  
Ronnie Sircar, Princeton University

The dramatic decline in oil prices, from around $110 per barrel in June 2014 to less than $50 in January 2015 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. We study how continuous time Cournot competitions, in which firms producing similar goods compete with one another by setting quantities, can be analyzed as continuum dynamic mean field games. We illustrate how the traditional oil producers may react in counter-intuitive ways in face of competition from alternative energy sources. This is a joint work with Patrick Chan.

Plenary V  
Chair: Harry Crane  
Modelling the Collapse of Financial Systems  
Tom Hurd, McMaster University

The list of possible channels of systemic risk (SR) includes correlated asset shocks, default contagion, funding liquidity contagion and market illiquidity effects. A number of deliberately simplified modelling frameworks, beginning with the Eisenberg-Noe 2001 model, aim to reveal the pure contagion effects that can lead to cascading chains of defaulted and illiquid financial institutions. It turns out that analytic methods can be brought to bear to determine the characteristics of such cascades on large random financial networks (RFN) that have a property we call local tree-like independence (LTI). In this talk, we review the conceptual basis of these methods in percolation theory on random graphs, and investigate how to extend them to interesting models of complex financial networks.
The presentation describes contributions of analytics and statistical methods to our understanding of insurance operations and markets. I will introduce insurance analytics and describe some current trends in analytics. I will discuss dependency modeling and how such approaches can help mitigate risk in insurance portfolios. Insurance as a discipline has long embraced analytics and market trends signal an even stronger relationship going forward.

“The Role of Analytics in the Regulation of Securities Markets”
Jonathan Sokobin, Chief Economist – FINRA

Multiple time series often exhibit lead-lag relationship among its component series. It is very challenging to identify this type of relationship when the number of series is large. We study the lead-lag relationship in the high dimensional context, using the maximum cross correlations and some other variants.

A Semiparametric Graphical Modeling Approach for Large-Scale Equity Selection
Han Liu, Princeton University

We propose a new stock selection strategy that exploits rebalancing returns and improves portfolio performance. To effectively harvest rebalancing gains, we apply ideas from elliptical-copula graphical modeling and stability inference to select stocks that are as independent as possible. The proposed elliptical-copula graphical model has a latent Gaussian representation; its structure can be effectively inferred using the regularized rank-based estimators. The resulting algorithm is computationally efficient and scales to large datasets. To show the efficacy of the proposed method, we apply it to conduct equity selection based on a 10-year healthcare stock dataset and a large 23-year stock dataset. Empirical tests show that the proposed method is superior to alternative strategies including a principal component analysis based approach and the classical Markowitz strategy based on the traditional buy-and-hold assumption.
Portfolio Liquidation and Related Problems, with Transaction Costs and Parameter Uncertainty: Dynamic Strategies for Optimal Execution
Lee Dicker, Rutgers University

We formulate the optimal execution problem as a multistage stochastic optimization problem with a mean-variance objective function and, following a technique proposed by Lai et al. (2011), solve the problem by reducing it to a family of simpler, more standard optimization problems. The optimal strategies that we find are dynamic strategies, which differ from the static execution strategies discovered by Almgren & Chriss (2001) in their landmark work. Our proposed framework naturally accommodates parameter uncertainty and many popular transaction cost models, along with other important features of realistic portfolio optimization problems.

(1B) Recent Advances in Financial Mathematics: Pricing and Hedging
Chair: Tiong Wee Lim, Organizer: Hongzhong Zhang

Arbitrage-Free Pricing of XVA
Stephan Sturm, Worcester Polytechnic Institute

We introduce a framework for computing the total valuation adjustment (XVA) of a European claim accounting for funding costs, counterparty risk, and collateral mitigation. Based on no-arbitrage arguments, we derive the nonlinear backward stochastic differential equations (BSDEs) associated with the replicating portfolios of long and short positions in the claim. This leads to defining buyer and seller’s XVAs which in turn identify a no-arbitrage band. When borrowing and lending rates coincide we provide a fully explicit expression for the uniquely determined price of XVA. When they differ, we derive the semi-linear partial differential equations (PDEs) associated with the non-linear BSDEs. We use them to conduct a numerical analysis showing high sensitivity of the no-arbitrage band and replicating strategies to funding spreads and collateral levels. This is joint work with Maxim Bichuch (WPI) and Agostino Capponi (Columbia).

Convolutional Autoregressive Models for Functional Time Series with an Application of Implied Volatility Curves
Xialu Liu, Rutgers University

Functional data analysis has became an increasingly popular class of problems in statistical research. However, functional data observed over time with serial dependence remains a less studied area. Motivated by Bosq (2000), who first introduced the functional autoregressive (FAR) models, we propose a convolutional functional autoregressive (CFAR) model, where the function at time t is a result of the sum of convolutions of the past functions with a set of convolution functions, plus a noise process, mimicking the autoregressive process. We adopt a sieve estimation procedure based on B-spline approximation of the convolution functions. We establish convergence rate of the proposed estimator, and investigate its theoretical properties. The model building, model validation, and prediction procedures are also developed. An application of implied volatility curves is presented.
Optimal Multiple Stopping with Negative Discount Rate and Random Refraction Times under Lévy Models
Hongzhong Zhang, Columbia University

We study an optimal multiple stopping problem driven by exponential Levy processes. Our model allows for a negative effective discount rate, which arises in a number of financial applications such as stock loans and real options. Moreover, successive exercise opportunities are separated by i.i.d. random refraction times. Under a wide class of Levy models, we rigorously show that the optimal strategy to exercise successive call options is uniquely characterized by a sequence of up-crossing hitting times. Joint work with Tim Leung (Columbia University) and Kazutoshi Yamasaki (Kansai University).

(1C) Systemic Risk and Economic Uncertainty
Chair: Ciomec Moallemi, Organzer: Agostino Capponi

Liability Concentration and Systemic Losses in Financial Network
Agostino Capponi, Columbia University

We 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 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 concentration results, supports regulatory policies aiming at limiting the size of gross exposures toward individual counterparties. (Joint work with David D. Yao and Peng Chu Chen).

Efficiency, Stability and Contagion in Financial Networks
Matt Elliott, California Institute of Technology

We consider a financial system that is subject to small and large asset specific shocks. While interconnections allows organizations to insure against small shocks, such connections also facilitate contagion in the presence of larger shock. When large shocks are relatively rare, the socially optimal network comprises of many highly interdependent clusters, with strong connections within cluster and weak connections across cluster. This social planners’ solution minimizes the number or defaults and maximizes payments to debt holders. Assuming organizations maximize shareholder value we look for stable financial networks in which no pair of organizations has a profitable trade. There is a general tension between stability and efficiency driven by the different incentives of shareholders and debtholders. However, when there are no default costs all efficient networks are stable. (Joint work with Jonathon Hazell)
Uncertainty Quantification and the Certification Problem: An Application to Financial Stress Testing
Mark Flood, Office of Financial Research – US Treasury

We extract from the yield curve a new measure of fundamental economic uncertainty, based on McDiarmid’s distance and related methods for optimal uncertainty quantification (OUQ). OUQ seeks analytical bounds on a system’s behavior, even where the underlying data-generating process and system response function are incompletely specified. We use OUQ to stress test a simple fixed-income portfolio, certifying its safety—i.e., that potential losses will be “small” in an appropriate sense. The results give explicit tradeoffs between: scenario count, maximum loss, test horizon, and confidence level. Uncertainty peaks in late 2008, weakening certification assurances just when they are needed most.

(1D) Volatility and Related Topics
Chair: Rong Chen

Optimal Switching Problems under Partial Information
Kai Li, Uppsala University

In this talk we study an optimal switching problem under partial information. In our model the agent/manager/investor attempts to maximize the expected reward by switching between different states/investment opportunities. However, he is not fully aware of his environment and only an observation process, which contains partial information about the environment/underlying, is accessible. It is based on the partial information carried by this observation process that all decisions must be made. We propose a probabilistic numerical algorithm based on dynamic programming, regression Monte Carlo methods, and stochastic filtering theory to compute the value function. The approximation of the value function and the corresponding convergence result are obtained when the underlying and observation processes satisfy the linear Kalman-Bucy setting. A numerical example is included to show some specific features of partial information. This talk is joint work with K. Nyström and M. Olofsson.

Inference for Time Series Regression Models with Weakly Dependent and Heteroscedastic Errors
Yeonwoo Rho, Michigan Technological University of Illinois at Urbana-Champaign

Error processes in a regression model for financial time series often exhibits some departures from the stationary assumption such as changing unconditional variances. In this talk, we introduce two such data generating processes for the error series, linear processes with heteroscedastic innovations and the modulated stationary processes, and propose a significance test of fixed repressors that is robust to the heteroscedastic behavior in our error series. We adopt the recently developed self-normalized approach to avoid the difficulty involved in the estimation of the asymptotic variance of the ordinary least squares estimator. The limiting distribution of the self-normalized quantity is non-pivotal but can be consistently approximated by using the wild bootstrap, which is not consistent in general without studentization. Simulation results will be provided, which demonstrates favorable coverage properties of the proposed method in comparison with alternative ones. This talk is based on a recently accepted paper under the same title.
Extreme Quantile Estimation by Using Limited Historical Data and Scenario Assessments
Helgard Raubenheimer, Centre for Business Mathematics and Informatics, North-West University

Many banks use the loss distribution approach in their advanced measurement models to estimate economic capital. This boils down to estimating the 99.9% VaR of the aggregate loss distribution and is notoriously difficult to do accurately. Also, it is well-known that the accuracy with which the tail of the loss severity distribution is estimated is the most important driver in determining a reasonable estimate of economic capital. To this end, banks use internal data and external data (jointly referred to as historical data) as well as scenario assessments in their endeavor to improve the accuracy with which the severity distribution is estimated. In this paper we propose a simple new method whereby the severity distribution may be estimated using historical data and experts’ scenario assessments jointly. The way in which historical data and scenario assessments are integrated incorporates measures of agreement between these data sources, which can be used to evaluate the quality of both. In particular we show that the procedure has definite advantages over traditional methods where the severity distribution is modelled and fitted separately for the body and tail parts, with the body part based only on historical data and the tail part on scenario assessments.

(2A) Financial Time Series (I)
Chair: David Matteson, Organizer: Shiqing Ling

A General Approach for Drawdown (Drawup) of Time-Homogeneous Markov Processes
Bin Li, Waterloo University

Drawdown (resp. drawup) of a stochastic process, also referred as the reacted process at the running maximum (resp. minimum), is a classical problem in applied probability and has wide applications in fund management industry, actuarial science, and statistics. In this paper, for time-homogeneous Markov processes, we propose a general and unified approach to the distributional study of various drawdown quantities. In general, our results reduce the drawdown problematic to the fundamental two-sided exit problematic. In particular, explicit forms are available when the underlying process has only one-sided jumps or is a L\'evy process (possibly with two-sided jumps). This is a joint work with David Landriault and Hongzhong Zhang.

Estimating multivariate GARCH and Stochastic Correlation models equation by equation
Jean-Michel Zakoian, Lille University

This paper investigates the estimation of a wide class of multivariate volatility models. Instead of estimating an m-multivariate volatility model, a much simpler and numerically efficient method consists in estimating m univariate GARCH-type models Equation by Equation (EbE) in the first step, and a correlation matrix in the second step. Strong consistency and asymptotic normality (CAN) of the EbE estimator are established in a very general framework, including Dynamic Conditional Correlation (DCC) models. The EbE estimator can be used to test the restrictions imposed by a particular MGARCH specification. For general Constant Conditional Correlation (CCC) models, we obtain the CAN of the two-step estimator. Comparisons with the global method, in which the model parameters are estimated in one step, are provided. Monte-Carlo experiments and applications to financial series illustrate the interest of the approach.
Inference for Heavy-Tailed and Multiple-Threshold Double Autoregressive Models
Yang Yaxing, Hongkong University of Science and Technology
In this talk, a systematic inference procedure for heavy-tailed and multiple-threshold double autoregressive (MTDAR) models is developed. We first study its quasi-maximum exponential likelihood estimator (QMELE). It is shown that the estimated thresholds are $n$-consistent, each of which converges weakly to the smallest minimizer of a two-sided compound Poisson process. The remaining parameters are $\sqrt{n}$-consistent and asymptotically normal. Based on this theory, a score-based test is developed to identify the number of thresholds in the model. Furthermore, we construct a mixed sign-based portmanteau test for model checking. Simulation study is carried out to access the performance of our procedure and a real example is given.

(2B) Advances in Derivative Pricing and Risk
Chair: Xiaolu Liu, Organizer: Rong Chen
Pricing of Path-dependent Basket Options via Bounds
Alex Novikov, University of Technology, Sydney
We set out to provide a general framework for the pricing of path dependent basket options via lower and upper bounds. This class of options includes European Asian, basket, options on the volume-weighted average price (VWAP) and American-type basket options. The use of lower and upper bounds is proposed in response to the inherent difficulty in identifying analytical representations for the true price of these options and the requirement for numerical procedures to be fast and efficient. We demonstrate that, in some cases lower and upper bounds allow for the dimensionality of the problem to be reduced and that these methods provide reasonable approximations to the price of the option. The presentation is based on joint research with Scott Alexander, Juri Hinz, Nino Kordzakhia and Tim Ling.

Measuring Credit Risk of Individual Corporate Bonds in US Energy Sector
Takeaki Kariya, Meiji University & Josai International University
In this paper, using the credit risk price spread (CRiPS) and the standardized credit risk price spread (S-CRiPS) associated with Kariya’s (2013) corporate bond (KCB) model, we make empirical credit risk analysis on individual corporate bonds (CBs) in the US energy sector. Applying the principal component analysis method to the S-CRiPS, we also categorize individual CBs into three different groups and show the characteristics of the price and S-CRiPS fluctuations in each group. Secondly, using the market credit rating scheme (M-Rating) proposed by Kariya et al. (2014), we make the credit-homogeneous groups of CBs and show that our rating scheme is empirically very useful. Thirdly via KCB model with a set of cross-sectional CB and government bond (GB) price data, we derive a term structure of default probabilities (TSDPs), which reflect the investors’ views and perspectives on the future default probabilities implicitly implied by the CB prices for each credit homogeneous group. Throughout this paper we find that our credit risk measure for individual CBs work effectively and can timely provide the market-based information.

Models of Bank Runs and Mean Field Games of Timing
Rene Carmona, Princeton University
Option Hedging Using an Adaptive Control Approach
Tiong Wee Lim, National University of Singapore

We present an adaptive approach to option hedging, which is developed to address the issues of modeling stock price dynamics and transaction costs in hedging. Our approach modifies Black-Scholes delta-hedging by incorporating features of the hedging strategies associated with the stochastic control problem of option hedging in the presence of transaction costs. The adaptive approach performs well in both the simulation and empirical studies.

Hidden Illiquidity with Multiple Central Counterparties
Ciamac C. Moallemi, Graduate School of Business, Columbia University

Regulatory changes are transforming the multi-trillion dollar swaps market from a network of bilateral contracts to one in which swaps are cleared through central counterparties (CCPs). The stability of the new framework depends on the resilience of CCPs. Margin requirements are a CCP's first line of defense against the default of a counterparty. To capture liquidity costs at default, margin requirements need to increase super-linearly in position size. However, convex margin requirements create an incentive for a swaps dealer to split its positions across multiple CCPs, effectively "hiding" potential liquidation costs from each CCP. To compensate, each CCP needs to set higher margin requirements than it would in isolation. In a model with two CCPs, we define an equilibrium as a pair of margin schedules through which both CCPs collect sufficient margin under a dealer's optimal allocation of trades. In the case of linear price impact, we show that a necessary and sufficient condition for the existence of an equilibrium is that the two CCPs agree on liquidity costs, and we characterize all equilibria when this holds. A difference in views can lead to a race to the bottom. We provide extensions of this result and discuss its implications for CCP oversight and risk management. Joint work with Paul Glasserman and Kai Yuan.

Estimating the Correlation Matrix of Credit Default Swaps for Market Risk Management
Richard Neuberg, Department of Statistics, Columbia University

We analyze correlation matrix estimation from the perspective of market risk management, where the goal is to obtain accurate estimates of portfolio risk across essentially all portfolios—even those with small standard deviations. We use the portfolio perspective to develop and evaluate estimator loss functions, and we propose a simple but effective visualization tool to compare alternative estimators across a wide range of portfolios. These methods are applied to credit default swaps (CDS), for which correlation matrices are used to set portfolio margin requirements for central clearing. Among the methods we test, the graphical lasso estimator performs particularly well. The graphical lasso and a hierarchical clustering estimator also yield economically meaningful representations of market structure through a graphical model and a hierarchy, respectively. We find that credit default swap returns are driven by a strong market factor, but that the effect of natural candidates for other observable market factors is small. We also examine the relationship between credit default swap correlations and implied correlations extracted from equity prices through distance-to-default measures. The difference between actual and implied returns is driven by a common factor that may reflect a premium for risk and possibly liquidity.
Finite Horizon Time Inhomogeneous Singular Control Problem of One-Dimensional Diffusion via Dynkin Game
Yipeng Yang, Math Department, University of Houston

The Hamilton-Jacobi-Bellman equation (HJB) associated with the time inhomogeneous singular control problem is a parabolic partial differential equation, and the existence of a classical solution is usually difficult to prove. In this paper, a finite horizon stochastic singular control problem of one dimensional diffusion is solved via a time inhomogeneous zero-sum game (Dynkin game). The regularity of the value function of the Dynkin game is investigated, and its integrated form coincides with the value function of the singular control problem. We provide conditions under which a classical solution to the associated HJB equation exists, thus the usual viscosity solution approach is avoided. We also show that the optimal control policy is to reflect the diffusion between two time inhomogeneous boundaries. For a general terminal cost function, we showed that the optimal control involves a possible impulse at maturity.

Equilibrium Asset Pricing with Rational and Irrational Investors
Xuedong He, Department of IEOR, Columbia University

We study a multi-period equilibrium asset pricing model with EZ agents whose preferences for consumption are represented by the classical Epstein-Zin recursive utility and with LA agents who receive additional utility of trading gains and losses and are averse to losses. We propose an equilibrium gain-loss ratio for stocks and show that the LA agents hold less (more) stocks than the EZ agents if and only if the LA agents' loss aversion degree is larger (less) than this ratio. With myopic EZ and LA agents, we prove the existence of the equilibrium and the market dominance of the EZ agents in the long run. Finally, we find that with reasonable parameter values, the equilibrium asset prices in our heterogeneous-agent model is quantitatively similar to those in an economy with a representative agent whose preferences are the average of the preferences of the agents in our model. This result, which is in contrast to the conclusion in Chapman and Polkovnichenko [J. Finance, 2009, 64, 1863--1887], justifies the extensive use of representative-agent models in the behavioral asset pricing literature.

Modeling and Pricing of CAT Bonds: the Extreme Value Approach
Fan Yang, Department of Statistics and Actuarial Science, University of Waterloo

Catastrophe (CAT) bonds are important financial instruments to transfer risk from reinsurance markets to capital markets. A CAT bond usually covers the last layer loss. Extreme value theory can be employed to model such high losses. It is well known that the fair premium of a CAT bond is based on the expected loss. Therefore, in the first part, we derive asymptotics for the expected loss to show how the choices of layer affect the fair premium when the loss variable follows a distribution function from a max-domain of attraction. In the second part, we consider a special CAT bond on California earthquakes with parametric trigger. Peaks over threshold method is used to analyze earthquake data. Further, we show the accuracy of extreme value modeling.
Firm's credit risk and the risk of structural breaks in financial market
Haipeng Xing, State University of New York, Stony Brook

Various sudden shifts in financial market conditions over the past decades have demonstrated the significant impact of market structural breaks on firms' credit behavior. To characterize such effect quantitatively, we develop a continuous-time modulated Markov model for firms' credit rating transitions with the possibility of market structural breaks. The model takes a semi-parametric multiplicative regression form, in which the effects of firms' observable covariates and macroeconomic variables are represented parametrically and nonparametrically, respectively, and the frailty effects of unobserved firm-specific and marketwide variables are incorporated via the integration form of the model assumption. We further develop a mixed-estimating-equation approach to make inference on the effect of market variations, baseline intensities of all firms' credit rating transitions, and rating transition intensities for each individual firm. We then use the developed model and inference procedure to analyze the monthly credit rating of U.S. firms from January 1986 to December 2012, and study the effect of market structural breaks on firms' credit rating transitions.

Clustering from Categorical Data Sequences
Harry Crane, Rutgers University

We discuss a combinatorial stochastic process model for categorical data sequences that frequently occur in genetics, political science, and item response theory. The model is particularly attractive for cluster analysis, as it establishes a clear interpretation of the data as repeated noisy measurements of a true clustering parameter. The model is also well-equipped to handle missing observations, perform out-of-sample inference, and accommodate both independent and dependent data sequences. In addition, its clustering parameter lies in the unrestricted space of partitions, so that the number of clusters need not be specified beforehand. We discuss several aspects of this model and demonstrate it on data sets from genetics, political science, and legal studies.

A Bayesian Multivariate Functional Dynamic Linear Model
David S. Matteson, Cornell University

We present a Bayesian approach for modeling multivariate, dependent functional data. To account for the three dominant structural features in the data—functional, time dependent, and multivariate components—we extend hierarchical dynamic linear models for multivariate time series to the functional data setting. We also develop Bayesian spline theory in a more general constrained optimization framework. The proposed methods identify a time-invariant functional basis for the functional observations, which is smooth and interpretable, and can be made common across multivariate observations for additional information sharing. The Bayesian framework permits joint estimation of the model parameters, provides exact inference (up to MCMC error) on specific parameters, and allows generalized dependence structures. Sampling from the posterior distribution is accomplished with an efficient Gibbs sampling algorithm. We illustrate the proposed framework with multi-economy yield curve data from the recent global recession. This talk is based on joint work with Daniel R. Kowal and David Ruppert, available here: http://arxiv.org/abs/1411.0764
Optimal Mean Reversion Trading with Transaction Costs
Tim Leung, IOR Department, Columbia University

We study the optimal timing of trades under mean-reverting price dynamics subject to fixed transaction costs. We first consider an optimal double stopping approach to determine the optimal times to enter and subsequently exit the market when prices are driven by an Ornstein-Uhlenbeck (OU), exponential OU, or CIR process. In addition, we analyze a related optimal switching problem with an infinite sequence of trades, and identify the conditions under which the double stopping and switching problems admit the same optimal entry and/or exit timing strategies. Among our results, we find that the investor generally enters when the price is low, but may find it optimal to wait if the current price is sufficiently close to zero, leading to a disconnected continuation (waiting) region for entry. Numerical results are provided to illustrate the dependence of timing strategies on model parameters and transaction costs.

Optimal Execution with Uncertain Order Fills
Tai-Ho Wang, Department of Mathematics, Baruch College

In this talk we present an extension of the classical price impact model of Almgren and Chriss to incorporate the uncertainty of order fills. The extended model can be recast as alternatives to uncertain impact models, stochastic liquidity models, and an approximation of models for liquidation with limit orders. Optimal strategies are determined by maximizing the expected final P&L and various P&L-risk tradeoffs including utility maximization. Closed form expressions for optimal strategies are obtained in linear cases. The results suggest a type of adaptive volume weighted average price (VWAP) and adaptive Almgren-Chriss strategies. Possible generalizations to transient impact models are also discussed. The talk is based on a joint work with Xue Cheng of Peking University.

Optimal Investment with Transaction Costs and Stochastic Volatility
Maxim Bichuch, Department of Mathematical Sciences, Worcester Polytechnic Institute

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 long-run growth rate problem when both complexities are present, using separation of time scales approximations. This leads to perturbation analysis of an eigenvalue problem. We find the first term in the asymptotic expansion in the time scale parameter, of the optimal long-term growth rate, and of the optimal strategy, for fixed small transaction costs.
Complete Analytical Solution of the Heston Model for Pricing Vanilla European and American Options and Representing their Value-at-Risk

Alexander Izmailov, Market Memory Trading

An explicit formulation of the theory of options based on their closed-form probability density functions was discussed in previous talk. In this follow on talk, results derived from the application of this formulation are reported for pricing vanilla European- and American-style options in the presence of stochastic volatility (Heston model), enabling complete analytical resolution of essentially all problems associated with options considered within the Heston Model.

Understanding Derivatives through Their Probability Density Functions

Brian Shay, Market Memory Trading and Hunter College, CUNY

An explicit formulation of the theory of options based on their closed-form probability density functions is introduced: An ground breaking analytical framework for pricing options exactly is presented. This analytical framework comprises not only vanilla European- and American-style options, but also prices Asian options exactly. However, more than that it enables compete analytical resolution of essentially any problem associated with Asian options.

Analysis of The Hull-White Method For Arithmetic Average Asian Options

Praktik Ramprasad, Rutgers University

The Hull-White Method (HWM) to price Asian options asymptotically converges to the exact solution, but computing accurate prices this way is time consuming. Using exact closed-form results provided by Market Memory Trading LLC, we derive an empirical formula for the HWM grid spacing which is used to compute highly accurate prices within the HWM almost instantaneously.

Assessment of Accuracy of Finite Difference Methods in Evaluation of Options within Heston Model

Chencheng Cai, Rutgers University

The recent analytical closed-form result (http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2549033) discovered by Market Memory Trading L.L.C. (“MMT”) for the probability density function of the European style options with stochastic volatility, considered within the Heston model, has allowed for the first time an opportunity to assess the approximate nature of various numerical methods used for evaluation of these options. Our goal here is to investigate the accuracy of the popular Crank-Nicolson Method (CNM), a two dimensional variant of the finite difference method, applied to these options. For brevity, studies reported are restricted to call options with a range of levels of "moneyness".
Bias and Artifact Trade-off in Modeling Temporal Trend of Insurance Purchase Data
Wenjiang Fu, University of Houston

In economics, marketing research and business management, it is important to estimate accurately the temporal trend of sales of products or the market share of a business during a period of time. Often the sales of products vary with the age of consumers (e.g. sales of life insurance policies). To estimate the temporal trend across a number of years, a summary value (e.g. yearly sales or percentage) needs to be estimated based on a sequence of age-specific sales or percentages. However, such a task is well known to be complex because of the Simpson’s paradox and because the age structure varies with time due to aging of the population. It is known that the crude rate method heavily depends on the age structure and drastically varies across time periods even if the age-specific sales or percentages remain the same, resulting in inappropriate trend estimation or comparison across time periods. A direct age-standardization method has been employed in the literature to calculate a summary value using the age-structure of a standard population. For example, using the US 2000 population age structure to calculate the age-adjusted percentage or sales of US life insurance policies. The same method has been applied to demography, public health and sociology.

Although the direct age-standardization method has become the “standard” procedure, it has been criticized in the literature for the lack of justification and for generating statistical illusions. In this talk, I will study the direct age-standardization using statistical framework, point out that the age-standardization procedure inevitably introduces bias, and further provide an upper bound of such bias. In particular, I demonstrate that using the age structure of the US 2000 Standard Population leads to severe overestimation of the sales of US life insurance policies. Meanwhile, the crude method yields incomparable summary statistics because of its artifact introduced by varying age structure. I will then introduce a novel mean reference population method for a bias-artifact trade off, which removes the artifact, minimizes the bias, and largely improves the estimation accuracy. This is a joint work with Shuangge Ma, David Todem and Martina Fu.

Dynamic Modeling and Prediction of Risk Neutral Densities
Rong Chen, Rutgers University

Risk neutral density is extensively used in option pricing and risk management in finance. It is often implied using observed option prices through a complex nonlinear relationship. In this study, we model the dynamic structure of risk neutral density through time, investigate modeling approach, estimation method and prediction performances. State space models, Kalman filter and sequential Monte Carlo methods are used. Simulation and real data examples are presented.

High Performance Computations for Statistical Methods in High-Frequency Finance
Jian Zou, Worcester Polytechnic Institute

Financial statistics covers a wide array of applications in the financial world, such as (high frequency) trading, risk management, pricing and valuation of securities and derivatives, and various business and economic analytics. Portfolio allocation is one of the most important problems in financial risk management. One most challenging part in portfolio allocation is the tremendous amount of data and the optimization procedures that require computing power beyond the currently available desktop systems. In this article, we focus on the portfolio allocation problem using high-frequency financial data, and propose a hybrid parallelization solution to carry out efficient asset allocations in a large portfolio via intra-day high-frequency data. We exploit a variety of HPC techniques, including
parallel R, Intel Math Kernel Library, and automatic offloading to Intel Xeon Phi coprocessor in particular to speed up the simulation and optimization procedures in our statistical investigations. Our numerical studies are based on high-frequency price data on stocks traded in New York Stock Exchange in 2011. The analysis results show that portfolios constructed using high-frequency approach generally perform well by pooling together the strengths of regularization and estimation from a risk management perspective. Using a combination of software and hardware parallelism, we demonstrate a high level of performance on high-frequency financial statistics.

Sequential Detection and Surveillance in Hierarchical Networks in Risk Management
Milan Shen, Stanford University

After a brief overview of core-periphery networks in measuring and monitoring systemic risk and hierarchical networks in manufacturing processes and corporate organizations, we describe some recent work on sequential detection and surveillance in these networks.

A Spherical Monte Carlo Method for Financial Option Pricing
Huei-Wen Teng, Graduate Institute of Statistics, National Central University

Monte Carlo method is an indispensable tool for pricing financial options in complicated cases, but it is known for its low convergence. This paper proposes a simple simulation scheme that utilizes the spherical transformation for a spherical distribution so that a predetermined set of points on the unit sphere constructed can be used as a random integration rule. Substantial improvements of the proposed scheme in terms of variance reduction and computational time are demonstrated via extensive numerical experiments in pricing exotic options under GARCH models.

On the Impulse Control Problem with Outside Jumps
Makoto Goto, Hokkaido University, Japan

In this paper, we study the impulse control problem with outside jumps. As represented by (s,S) policies, impulse control problems usually have inside jumps. Namely, when the inventory level goes down and hits a threshold, it jumps up by the order placement. However, in terms of capacity choice problems, firms should install additional capacities when the demand is increasing. That is, the impulse control problem we consider has outside jumps. Our approach is inspired by Guo and Tomecek (2008) who study connections between singular control and optimal switching problems.
Estimation of Moment Parameters in High Dimensional Elliptical Models
Koushiki Bose, Princeton University

The Gaussian assumption often fails to capture the heavy tails displayed by financial returns. We model financial data by assuming their joint distribution comes from a multivariate elliptical family. We aim to estimate the kurtosis parameter and higher moments of the distribution, which reveal information about the tail behavior of the data. Existing estimators typically require a good estimate of the precision matrix, which assumes strict structural assumptions on either the covariance matrix or the precision matrix when data is high dimensional. We propose two methods that only takes an estimate of the covariance matrix. The success of the method requires that the covariance matrix is sparse or has an approximate factor model. We provide theoretical analysis showing the rates of convergence of our estimators. We have also applied our methods to synthetic financial data.

Multivariate Convex Regression for Options Pricing
Lauren Anne Hannah, Columbia University

We propose a new, nonparametric method for multivariate regression subject to convexity or concavity constraints on the response function. Convexity constraints are common in economics, statistics, operations research, financial engineering and optimization, but there is currently no multivariate method that is stable and computationally feasible for more than a few thousand observations. We introduce convex adaptive partitioning (CAP), which creates a globally convex regression model from locally linear estimates fit on adaptively selected covariate partitions. CAP is a computationally efficient, consistent method for convex regression. We demonstrate empirical performance by comparing the performance of CAP to other shape-constrained and unconstrained regression methods for predicting weekly wages and value function approximation for pricing American basket options.

Multi-Stage Model for Correlated Defaults
Cheng-Der Fuh, National Central University, Taiwan

Correlated defaults for multiple firms are complicated phenomenon in finance, however existing models are either simplified that contain little information, or complex that lose mathematical tractability. In this paper, we propose a structural form default model for multiple firms that preserves the rich information in structural form model, remains mathematical tractability, and captures empirical observed phenomenon. The model is divided into stages that, when any firm defaults, the model evolves into the next stage, where the firms would encounter a new set of default thresholds. By such, we are able to capture ‘contagion’ and other correlated default effects. This stage setting also provides us the mathematical tractability in the sense that, with the help of renewal theorem, we can provide asymptotic approximation for the joint probability of default times, which is critical for risk management. The results could be further applied for n-th to default swap pricing. Numerical results are also given for illustration.
Asymptotic Inference for Structurally Changed Threshold Autoregressive Models
Zhaoxing Gao, Hong Kong University of Science and Technology

In this talk, we investigate the least squares estimation of the structurally changed threshold AR models. It is shown that both estimated threshold and change-point are $n$-consistent, and they converge weakly to the smallest minimizer of a compound Poisson process and the location of minimas of a two-sided random walk, respectively. When the magnitude of changed parameters in the state regimes or in the time horizon is small, it is further shown that these limiting distributions can be approximated by a class of known distributions. Other estimated slope parameters are $\sqrt{n}$-consistent and asymptotically normal. We also include a new strong law of large number theorem of a strong mixing random sequence, which is independent of interest. Simulation study is carried out to access the performance of our procedure. A real data example is given to illustrate our theory.

Inference for ARMA Models with Unknown-Form and Heavy-Tailed GARCH-Type Noises
Shiqing Ling, Hong Kong University of Science and Technology

This paper develops a systematic procedure of statistical inference for the ARMA model with unknown-form and heavy-tailed G/ARCH-type noises. We first investigate the least absolute deviation (LAD) estimator and the self-weighted LAD estimator for the model. Both estimators are shown to be strongly consistent and asymptotically normal when the noise has a finite variance and infinite variance, respectively. The rates of convergence of the LAD and the self-weighted LAD estimators are $n^\alpha (1/2)$ which is faster than those of LSE for the AR model when the tail index of GARCH noises is in $(0, 4)$, and thus they are more efficient in this case. Since their asymptotic covariance matrices cannot be estimated directly from the sample, we develop the random weighting approach for statistical inference under this nonstandard case. We further propose a novel sign based portmanteau test for model adequacy. Simulation study is carried out to assess the performance of our procedure and two real illustrating examples are given.

Multivariate Longitudinal Modeling of Insurance Claims Using Copulas
Peng Shi, School of Business, University of Wisconsin, Madison

In property and casualty insurance, claims management is featured with modeling of semi-continuous insurance costs associated with individual risk transfer. This practice is further complicated by the multilevel structure of the insurance claims data, where a contract often contains a group of policyholders, each policyholder is insured under multiple types of coverage, and the contract is repeatedly observed over time. The data hierarchy introduces complex dependence structure among claims and leads to diversification in the insurer’s liability portfolio. To capture the unique features of policy-level insurance costs, we propose a copula regression for the multivariate longitudinal claims. In the model, the Tweedie double generalized linear model is employed to examine the mixed claim cost of each coverage type, and a Gaussian copula is specified to accommodate the cross-sectional and temporal dependence among the multilevel claims. Inference is based on the composite likelihood approach and the properties of parameter estimates are investigated through simulation. When applied to a portfolio of personal automobile policies from a Canadian insurer, we show that the proposed copula model provides valuable insights to an insurer’s claims management process.
Optimal Execution in Hong Kong given a Market-On-Close Benchmark
Christoph Frei, University of Alberta
At the Hong Kong Stock Exchange, the median of five prices taken over the last minute of trading is currently chosen as the closing price. We introduce a stochastic control formulation of how to optimally trade in order to target such a median benchmark. We solve this problem by providing an explicit and efficient algorithm, taking the dependence structure of the prices into account. Implementing the algorithm on the stocks of the Hang Seng Index, we quantify the risk intrinsic to targeting a median benchmark and analyze the risk reduction resulted from the algorithm. The talk is based on joint work with Nicholas Westray.

Optimal Liquidation Trajectories for the Almgren-Chriss Model with Lévy Processes
Arne Lokka, London School of Economics
We consider an optimal liquidation problem with infinite horizon in the Almgren-Chriss framework, where the unaffected asset price follows a Lévy process. The temporary price impact is described by a general function which satisfies some reasonable conditions. We consider an investor with constant absolute risk aversion, who wants to maximize the expected utility of the cash received from the sale of his assets, and show that this problem can be reduced to a deterministic optimisation problem which we are able to solve explicitly. In order to compare our results with exponential Lévy models, which provides a very good statistical fit with observed asset price data for short time horizons, we derive the (linear) Lévy process approximation of such models. In particular we derive expressions for the Lévy process approximation of the exponential Variance-Gamma Lévy process, and study properties of the corresponding optimal liquidation strategy. We find that for the power-law temporary impact function, the optimal strategy is to liquidate so quickly that it may be practically impossible. We therefore study the case where the temporary impact function follows a power-law for small liquidation speeds, but tends faster to infinity than a power-law as the liquidation speed tends to infinity. In particular, we obtain an explicit expression for the connection between the temporary impact function for the Lévy model and the temporary impact function for the Brownian motion model, for which the optimal liquidation strategies for the two models coincide.

A Closed-Form Execution Strategy to Target VWAP
Sebastian Jaimungal, University of Toronto
We provide two explicit closed-form optimal execution strategies to target VWAP resulting from solutions of optimal stochastic control problems which target traded volume. We do this under very general assumptions about the stochastic process followed by the volume traded in the market, and, unlike earlier studies, we account for permanent price impact stemming from order-flow of the agent and all other traders. One of the strategies consists of TWAP adjusted upward by a fraction of instantaneous order-flow and adjusted downward by the average order-flow that is expected over the remaining life of the strategy. The other strategy consists of the Almgren-Chriss execution strategy adjusted by the expected volume and net order-flow during the remaining life of the strategy. We calibrate model parameters to five stocks traded in NASDAQ (FARO, SMH, NTAP, ORCL, INTC) and use simulations to show that the strategies target VWAP very closely and on average outperform the target by between 0.10 and 8 basis points. This is joint work with Álvaro Cartea, University College London.
(6A) Topics on Portfolio Management
Chair: Peng Shi
Ranking Stocks from On-line Portals: Regression with Partially Observed Ranks on a Covariate
Johan Lim, Seoul National University

Dynamics of Order Positions in a Limit Order Book (LOB)
Zhao Ruan, University of California, Berkeley

The dynamics of an order position in a LOB is a critical yet missing piece when modeling the LOB and dealing with the inventory/execution risk with consideration of microstructure of the LOB. We will present some of our recent progress regarding the limiting behavior of that dynamics, including some explicit expressions for various quantities of interests.

Optimal Order Execution with Bounded Rate of Transaction
Xin Guo, University of California, Berkeley

In this problem, we considered an optimal execution model with transaction costs and with constraints on the transaction rates. Under one setting of the parameters, we showed that the optimal value function is the viscosity solution to the associated HJB equation. Under another setting of the parameters, we found the closed-form solution and the optimal control policy. Regularities of the value function are investigated too.

(6B) Hedging and Pricing in Incomplete Markets
Chair: Milan Shen, Organizer: Paolo Guasoni
Endogenous Current Coupon
Scott Robertson, Carnegie Mellon University

We consider the problem of identifying endogenous current coupons for To-Be-Announced (TBA) agency mortgage pass through securities. Current coupons play a crucial role in the mortgage industry for pricing and determining the relative value of mortgage backed securities. The current coupon is said to be endogenous if it gives rise to a fairly, or par valued, TBA. Since prepayments both affect the value of the mortgage and depend heavily upon the coupon, the identification of current coupons involves solving a highly non-trivial fixed point problem. In an intensity based, Markovian model where underlying economic factors affect prepayments, we solve the fixed point problem and hence identify the current coupon as a function of the underlying factors. The method of proof involves Schaefer's fixed point theorem, in conjunction with a delicate doubling of variables and localization argument. After proving existence of current coupons, we perform a perturbation analysis where prepayment intensities are perturbed off of a baseline intensity dependent only upon the factors. We obtain a unique current coupon up to leading orders of the perturbation and show that this approximation does very well in practice for estimating the current coupon. We also extend our analysis to cover defaults and heterogeneous groups within the mortgage pass through.
Quantile Hedging in a Semi-Static Market with Model Uncertainty
Gu Wang, University of Michigan

With model uncertainty characterized by a convex, possibly non-dominated set of probability measures, the investor minimizes the cost of hedging a path dependent contingent claim with a given expected success ratio, in a discrete-time, semi-static market of stocks and options. We prove duality results that link the problem of quantile hedging to a randomized composite hypothesis test. By assuming a compact path space, an arbitrage-free discretization of the market is proposed as an approximation. The discretized market has a dominating measure, which enables us to calculate the quantile hedging price by applying the generalized Neyman-Pearson Lemma. Finally, the performance of the approximate hedging strategy in the original market and the convergence of the quantile hedging price are analyzed.

An Expansion in the Model Space in the Context of Utility Maximization
Oleksii Mostovyi, University of Texas at Austin

In the framework of an incomplete financial market where the stock price dynamics is modeled by a continuous semi-martingale, an explicit first-order expansion formula for the power investor's value function - seen as a function of the underlying market price of risk process - is provided and its second-order error is quantified. The numerical examples illustrating the accuracy of the method are also given. (This talk is based on the joint work with Kasper Larsen and Gordan Zitkovic.)

(7A) Market Structure and Reform
Organizer and Chair: Neville O’Reilly

Equity Market Structure: How We Got Here and What's Next
Anthony Barchetto, BATS

A look at the progression of over 30 years of regulatory and technology change that have molded US equity market structure into what it is today.

Understanding Market Structure and Liquidity in Credit
David Krein, MarketAxess

Although corporate bond issuance is booming, serious flags have been raised over the trends in trading activity. We’ll review the structural and regulatory evolution over the last few years, beginning with the long-lingering shadow of the financial crisis and highlighting recent developments in sourcing new pools of liquidity.
A Darwinian approach to detecting accounting irregularities

Javed Jussa, Deutsche Bank – Quantitative Strategies Group

We discuss two approaches to identify accounting fraud. Based on the Benford’s law, we find when a firm’s accounting data violates the typical distributional property, it suggests a higher probability of accounting irregularity and lower returns. Using the AAER database, we analyze the characteristics of fraudulent companies and build a logit model to predict fraud.

Seven Sins of Quantitative Investment

Sheng, Wang - Deutsche Bank – Quantitative Strategies Group

We discuss the seven common biases model building. We compare various data normalization techniques; address the issues of signal decay/turnover/transaction costs; illustrate the asymmetric payoff patterns and the impact of short availability; show the optimal rebalancing frequency; and compare active management via multi-factor models versus smart beta investing via factor portfolios.

Cross-Dependent Volatility

Julien Guyon, Bloomberg LP and Columbia University

We propose a general framework for pricing and hedging derivatives in cross-dependent volatility (CDV) models, i.e., multi-asset models where the volatility of each asset is a function of not only its current or past levels, but also those of the other assets. We explain how to build all the CDV models that are calibrated to all the asset smiles, solving in particular the longstanding smiles calibration problem for the “cross-aware” multidimensional local volatility model.

CDV models are rich enough to be simultaneously calibrated to other instruments, such as basket smiles, and we show that we can fit a basket smile either by means of a correlation skew, like in the classical “cross-blind” multidimensional local volatility model, or using only the cross-dependency of volatilities itself, in a correlation-skew-free model, thus proving that steep basket skews are not necessarily a sign of correlation skew. We even build calibrated models whose correlation skews are opposite to the ones in the cross-blind models, e.g., large negative index skews but stocks less correlated when the market is down. All the calibration procedures use the particle method. Numerical results in the case of the FX smile triangle problem illustrate our results and the capabilities of CDV models.
Rough Volatility
Jim Gatheral, Baruch College, CUNY

Starting from the observation that increments of the log-realized-volatility possess a remarkably simple scaling property, we show that log-volatility behaves essentially as a fractional Brownian motion with Hurst exponent H of order 0.1, at any reasonable time scale. The resulting Rough Fractional Stochastic Volatility (RFSV) model is remarkably consistent with financial time series data. We then show how the RFSV model can be used to price claims on both the underlying and integrated volatility. We analyze in detail a simple case of this model, the rBergomi model. In particular, we find that the rBergomi model fits the SPX volatility markedly better than conventional Markovian stochastic volatility models, and with fewer parameters. Finally, we show that actual SPX variance swap curves seem to be consistent with model forecasts, with particular dramatic examples from the weekend of the collapse of Lehman Brothers and the Flash Crash.

Modeling Volatility Risk in Equity Options Markets
Doris Dobi, Courant

In the Black Scholes formulas for European option values under zero rates, the absolute values of the spot and strike derivatives are probabilities of finishing in the money under different numeraire. At each fixed term, one of these probabilities/deltas can be related to the other using a convex distortion function with a single free parameter $\sigma^2 > 0$. Using results from convex duality, we show that arbitrage-free option prices can always be generated by specifying a convex distortion function. We propose a parametrization of this convex distortion function that replaces the positive parameter $\sigma^2$ with an arbitrary positive function of a real-valued moneyness variable. As a result, the option prices generated by an arbitrary positive specification of our function are arbitrage-free. In contrast, option prices generated by an arbitrary positive specification of implied variance can contain cross-strike arbitrage. When our positive function is chosen to be a positive constant, the resulting European option prices are given by the Black Scholes formulas.

Transformations of volatility skews into leveraged volatility skews
Roger Lee, University of Chicago

We prove a set of simple relationships which directly link the volatility skew of a leveraged product with the volatility skew of the reference asset. Error estimates are included.
Asymptotics for rough stochastic volatility and Levy models
Hongzhong Zhang, Columbia University

Using the large deviation principle (LDP) for a re-scaled fractional Brownian motion \$B^H_t\$ where the rate function is defined via the reproducing kernel Hilbert space, we compute small-time asymptotics for a correlated fractional stochastic volatility model of the form \$dS_t=S_t\sigma(Y_t)\,dW_t+\rho\,dB_t\$, \$dY_t=dB^H_t\$; in particular, we show that \$S^t_{H-Half}\log S_t\$ satisfies the LDP as \$S \to 0\$ and the model has a well-defined implied volatility smile as \$S \to 0\$, when the log-moneyness \$k(t)=t^{\frac{H}{2}}\$. Thus the smile steepens to infinity or flattens to zero depending on whether \$S^0_{\min(0,\text{half})}\$ or \$S^0_{\min(\text{half},1)}\$, consistent with the results for the at-the-money skew in literature. We also compute large-time asymptotics for a fractional local-stochastic volatility model \$dS_t=S_t\sigma(Y_t)\,dW_t\$, \$dY_t=dB^H_t\$ and large-time asymptotics for European and barrier options under conventional and fractional exponential L\f(\k)e\vy models, using the deAcosta LDP for a L\f(\k)e\vy process on path space. As an aside, we also revisit the CGMY self-similar Variance Gamma model, which is shown to exhibit a short-maturity smile in the \$k(t)\sim t^{\frac{1}{2}}\$ parameterization used in FX option markets, and reproduces the empirically observed phenomenon that at-the-money digital calls are worth more than 0.5 as \$S \to 0\$.

(8C) Levered Portfolios
Organizer: Lisa Goldberg and Chair: Han Xiao

Determinants of Levered Portfolio Performance
Lisa Goldberg, Aperio Group, Berkley Associates, University of California, Berkeley

The cumulative return to a levered strategy is determined by five elements that fit together in a simple and useful formula. A previously undocumented element is the covariance between leverage and excess return to the fully invested source portfolio underlying the strategy. In an empirical study of (dynamically levered) volatility targeting strategies over the 84-year period 1929–2013, this covariance accounted for a reduction in return that substantially diminished the Sharpe ratio in all cases.

The Cost of Levering Equity through Futures
Nicholas Gunther, Open Analytics, Visible Market, UC Berkeley Center for Risk Mgmt. Research

Investors can lever through derivative markets without explicitly borrowing money. Some investment strategies that are popular with institutional fund managers require leveraging equity indices, either by explicit borrowing or through futures. Unlike explicit borrowing costs, costs of financing through futures contracts are unknown. We develop a theoretical method to infer the cost of financing leverage through index futures. The method makes use of an arbitrage relationship between the prices of the near and next futures contracts, two futures contracts expiring approximately three months apart on the same underlying index. This method overcomes (substantial) complications related to the daily settlement of futures contracts, margin accounts, and market segmentation. We apply our method to analyze strategies that lever the S&P 500 index. In this setting, spreads of Futures-Implied-Rates over Eurodollar Deposit rates approximately follow Ornstein-Uhlenbeck (OU) processes, which are used to determine the statistical significance of the differences in these rates. Our results are highly period dependent and they suggest that the Commodity Futures Modernization Act (CFMA) of 2000 may have caused a substantial market dislocation. Prior to the enactment of CFMA, it was significantly more expensive to lever the S&P index through futures than through explicit borrowing. Subsequent to the enactment, the situation was reversed.
A Dynamic Network Model Proposal for the Repo Market
Alex Sh koknik, Post-Doctoral Research Fellow, UC Center for Risk Management

The repo market is a crucial part of the U.S. financial infrastructure which supplies trillions of dollars in short-term funds to various financial institutions. Its instrument, the repo (or repurchase agreement), facilitates the efficient financing and sourcing of various securities. As highlighted by the crisis of 2007-09, the repo market incorporates leverage through the practice of rehypothecation, the re-use of repo collateral, amplifying its inherent systemic risk. In contrast to static equilibrium models in prior literature, we propose a dynamic model of a networked repo market. We illustrate the complex phenomena exhibited by the model and analyze its systemic properties. We propose the concept of “system leverage” and relate it to the stable functioning of the repo market. Empirical data is shown to offer support for predictions of our model.

(9A) Alpha and Risk Management
Organizer: Dan diBartolomeo and Chair: Rong Chen
Portfolio Optimization with VaR, CVaR, Skew and Kurtosis
Dan diBartolomeo, Northfield Information Services

Since the theoretical advent of mean-variance portfolio optimization in the 1950s there has been an ongoing debate as to the necessity of including higher moments of return distributions (skew and kurtosis) into the process. In recent years, the increasing regulatory focus on downside risk measures such as VaR and CVaR has extended the interest in this topic. This presentation will first identify the portfolio situations where the importance of higher moments appears to be economically material and statistically significant. We will then use the example of “catastrophe” bonds to illustrate two broad approaches to incorporate higher moments into portfolio optimization. In the first approach, we will review “full scale” optimization that explicitly includes skew and kurtosis in the objective function. In the second approach, we will consider using analytical techniques to reduce the four-moment problem to an approximately equivalent mean-variance problem, before solving conventionally. Due to the estimation error in the parameters, we find transforming the problem into mean-variance equivalence to be sufficient for all but the most extreme cases.

Smart Portfolios
Jason Macqueen, Northfield Information Systems

Smart Beta has become the latest fashion to conquer the investment community. There are now numerous indices and ETFs purporting to offer exposure to one or more investment styles, both in the USA and elsewhere. Its cheerleaders claim that Smart Beta investment products offer the alpha promise of active managers, without the corresponding drag on performance from fees. Large pension funds or endowments with several active managers will almost invariably find that their diversified equity portfolio, in aggregate, consists of a bet on the equity market plus a relatively small number of style factor bets, so that their fund’s performance will be that of the market, overlaid with various style tilts, and minus the managers’ fees. Put this way, it is easy to see the appeal of Smart Beta products. However, there are also critics of both the underlying concept and its many implementations. From a quant perspective, these are simply factor portfolios which offer significant exposure to the desired style factor, but the way in which many Smart Beta products are designed suggest that the style tilt will only have a modest effect on their performance. To suppose that a market-capitalisation-weighted portfolio of US stocks with high Book-to-Price ratios will provide a meaningful exposure to the Value premium is naïve at best, and weighting
by their “relative style attractiveness” is little better. Having a simple story to sell Smart Beta products comes at the price of leaving a lot of the Style premium on the table.

This talk will argue that the real added value to be gained from creating Smart Beta portfolios lies in the methodology used to create the Smart Portfolio, and that this, in turn, is the end result of taking care at each step of the portfolio construction process. The talk will cover several US Style strategies, each based on standard Style factors.

**Factor Investing: The Next Wave**  
**Raman Subramanian, MSCI**

The market continues to adopt factor investing -- which is increasingly attracting investors’ attention -- to further improve risk-adjusted portfolio returns. Now, institutional investors can implement these strategies through a transparent and cost efficient approach by tracking factor indexes. In this session we will explain the rationale for factor investing and the way indexes can be constructed and integrated into Portfolio Construction and Risk Analysis to reflect factor returns.

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**(9B) Advances in Options Price Modeling**  
**Organizer: Neville O’Reilly, Chair: Neville O’Reilly**

**A complete Analytical Solution of the Heston Model for Pricing Vanilla European and American Options and Representing their Value-at-Risk**  
**Alexander Izmailov, Market Memory Trading**

An explicit formulation of the theory of options based on their closed-form probability density functions was discussed in previous talk. In this follow on talk, results derived from the application of this formulation are reported for pricing vanilla European- and American-style options in the presence of stochastic volatility (Heston model), enabling complete analytical resolution of essentially all problems associated with options considered within the Heston Model.

**Understanding Derivatives through Their Probability Density Functions**  
**Brian Shay, Market Memory Trading and Hunter College, CUNY**

An explicit formulation of the theory of options based on their closed-form probability density functions was discussed in previous talk. In this follow on talk, results derived from the application of this formulation are reported for pricing vanilla European- and American-style options in the presence of stochastic volatility (Heston model), enabling complete analytical resolution of essentially all problems associated with options considered within the Heston Model.

**Analysis Of The Hull-White Method For Arithmetic Average Asian Options**  
**Praktik Ramprasad, Rutgers University**

The Hull-White Method (HWM) to price Asian options asymptotically converges to the exact solution, but computing accurate prices this way is time consuming. Using exact closed-form results provided by Market Memory Trading LLC, we derive an empirical formula for the HWM grid spacing which is used to compute highly accurate prices within the HWM almost instantaneously.
Assessment of Accuracy of Finite Difference Methods in Evaluation of Options within Heston Model

Chencheng Cai, Rutgers University

The recent analytical closed-form result (http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2549033) discovered by Market Memory Trading L.L.C. (“MMT”) for the probability density function of the European style options with stochastic volatility, considered within the Heston model, has allowed for the first time an opportunity to assess the approximate nature of various numerical methods used for evaluation of these options. Our goal here is to investigate the accuracy of the popular Crank-Nicolson Method (CNM), a two dimensional variant of the finite difference method, applied to these options. For brevity, studies reported are restricted to call options with a range of levels of "moneyness".

(9C) Data Analytics and Statistical Modeling in Financial Markets
Organizer and Chair: Tze Lai

“Big Data in Securitized Products Modeling”
Gangqiang Xia, Morgan Stanley

Securitization is a process of pooling various financial assets and repackaging them into new tradable securities. It is often hard to analyze securitized products because their cash flows depend on hundreds or thousands of underlying assets, and sometimes the underlying itself is a securitized product. In this talk, we discuss how to use large datasets, such as loan-level performance data, consumer credit data, housing transactions and prices etc., to model loan behavior and predict bond cash flows. We talk about the challenges in analyzing big data for securitized products, including data loading and storage, computational efficiency, model fitting and prediction.

Generalized Linear Mixed Models for SME Loan Default Prediction and Econometric Forecast Evaluation
Yong Su, Citigroup

Small and medium-sized enterprises (SMEs) play an important role in developed and developing economies, and a large number of financial institutions, varying from global banks to lending clubs, offer loan products for SMEs. We introduce a class of generalized linear mixed models (GLMMs) for default prediction of these loans, and carry out an empirical study to illustrate the methodology. In this connection we also discuss evaluation of the default probability forecasts and show how the GLMM-based forecasts compare with those based on logistic regression. This is joint work with Tze Leung Lai and Zhiyu Wang of Stanford University.

Financial Technology and Big-Data-Driven Quantitative Finance
Samuel Po-Shing Wong, 5Lattice Securities

This presentation will first focus on the relationship between Financial Technology and Subordinated Stochastic Process Model in Quantitative Finance. The second part will illustrate how to develop trading heuristics by performing simulation and optimization under Big Data Infrastructure.
Practical Limitations of the Fundamental Law
Michaud, Robert, New Frontier Advisors

Portfolio Optimization Under Uncertainty
David Esch, New Frontier Advisors

Too often the critical when-to-trade decision is based on suboptimal calendar and range trading rules. Proper portfolio monitoring is necessarily a statistical similarity test between currently held and new optimal portfolios. A particular difficulty for a valid statistical rule requires consideration of overlapping data often implicit in the definition of the two portfolios. We present two resampling-based algorithms defining a need-to-trade probability relative to overlapping data and inequality constrained Michaud optimization conditional on manager styles, mandates and objectives. The method may allow large-scale continuous automatable non-calendar based portfolio monitoring as well as statistical quadratic programming signal detection applications beyond finance.

Valuing Equities with Profit Factors
Nathan A. Tidd, Tidd Laboratories Inc.

Adapting familiar multi-factor modeling techniques to a new framework, Equity P/E Factor Models explain equity prices based on how firms generate profits (or not), delivering useful insights such as factor valuations that signal “alpha periods” and market premiums that reflect market expectations for firm-specific growth. This presentation provides an overview of the methodology and illustrates example usage for asset selection, buy/sell timing decisions, and portfolio analysis.
Equity Correlation Modeling
Sebastien Bossu, Ogee Group LLC & Pace University

Equity correlation matrices have structure and as a result the payoff of a correlation swap is strongly tied to top eigenelements. We present some fundamental bounds and propose an improved pricing model for correlation backed by variance dispersion strategies. This talk is related to the speaker’s latest book ADVANCED EQUITY DERIVATIVES: VOLATILITY & CORRELATION (Wiley 2014)

Seeking Factors in Execution Cost Reduction
Biquan Lin, BNY ConvergEx

Execution cost is affected by variety of factors presented in order characteristics, execution venues and market conditions. It includes: historical liquidity and volatility of stocks; order type and size; current momentum and quote imbalance of stocks; venue efficiency; index and peer stock movement. This presentation proposes some systematic approaches in examine all potential factors. Among them, we studied grid analysis, stepwise regression, and least angle regression (LARS) and analyzed the results obtained by these methods.

Multiperiod Portfolio Optimization with Transaction Costs
Gordon Ritter, GSA Capital

KVA for Counterparty Credit Risk Capital and CVA Capital
Andrew McClelland, Numerix

KVA is a recent addition to the family of XVA’s, capturing the cost of holding capital in reserve against the risk of trades. Whereas CVA and FVA require simulation of future exposures/collateral shortfalls, KVA requires simulation of future capital requirements. This presentation focuses on simulating future CCR and CVA capital requirements, highlighting the importance of future conditional expected exposure profiles, and discussing the evaluation of such profiles via LSMC. It is also seen that approximations for capital rules allow the KVA formulas to be evaluated approximately with the use of unconditional expected exposure profiles, as are used for CVA and FVA.

Short Course. Session 1
Sequential Monte Carlo Methods in Finance
Rong Chen & Tze Lai

Short Course. Session 2
Recent Developments in Portfolio Optimization and Algorithmic Trading
Gordon Ritter
Plenary Speakers Profile

Richard Davis, Columbia University

Richard Davis is the Howard Levene Professor of Statistics and Chair of Statistics at Columbia University. He is also president-elect of the Institute of Mathematical Statistics. He received his Ph.D. degree in Mathematics from the University of California at San Diego in 1979 and has held academic positions at MIT and Colorado State University in addition to numerous visiting positions. Recently he was a Hans Fischer Senior Fellow at the Technical University of Munich and Villum Kan Rasmussen Visiting Professor at the University of Copenhagen. Davis is a fellow of the Institute of Mathematical Statistics and the American Statistical Association, and is an elected member of the International Statistical Institute. He is co-author (with Peter Brockwell) of the bestselling books, "Time Series: Theory and Methods", "Introduction to Time Series and Forecasting", and the time series analysis computer software package, "ITSM2000". Together with Torben Andersen, Jens-Peter Kreiss, and Thomas Mikosch, he co-edited the "Handbook in Financial Time Series." In 1998, he won (with collaborator W. T. M. Dunsmuir) the Koopmans Prize for Econometric Theory.

He has served on the editorial boards of major journals in probability and statistics and most recently was Editor-in-Chief of Bernoulli, 2010-2012. He has advised/co-advised 31 PhD students and presented numerous short courses on time series and heavy-tailed modeling in Europe and South America. His research interests include time series, applied probability, extreme value theory, and spatial-temporal modeling.

EW (Jed) Frees, University of Wisconsin-Madison

Edward W. (Jed) Frees is the Assurant Health Insurance Professor of Actuarial Science at the University of Wisconsin-Madison. He received his Ph.D. in mathematical statistics in 1983 from the University of North Carolina at Chapel Hill and is a Fellow of both the Society of Actuaries (SoA) and the American Statistical Association (the only Fellow of both organizations). Professor Frees has provided extensive service to the profession, including serving as the founding chairperson of the SoA Education and Research Section, a member of the SoA Board of Directors, a Trustee of the Actuarial Foundation, the Editor of the North American Actuarial Journal, and as an actuarial representative to the Social Security Advisory Board's Technical Panel on Methods and Assumptions. At the UW School of Business, he served as department chair and as Associate Dean for Research and Ph.D. Programs. He has written three books; his most recent was published in 2010 by Cambridge University Press, entitled Regression Modeling with Actuarial and Financial Applications. Regarding his research, Professor Frees has also written over fifty articles that have appeared in the leading refereed academic journals and has won several awards for the quality of his work. He has won the Society of Actuaries’ Annual Prize for best paper published by the Society, the SoA’s Ed Lew Award for research in modeling, the Casualty Actuarial Society’s Hachmeister award, and the Halmstad Prize for best paper published in the actuarial literature (four times).
Tom Hurd, McMaster University

Tom Hurd is Professor of Mathematics at McMaster University in Canada. He turned to the mathematical study of financial markets in the late 1990s, following his earlier research in mathematical physics. Since then he has written on a wide range of financial topics, with publications in portfolio theory, interest rate modeling, and credit risk. Over the past few years, his work has focussed on the mathematical modelling of systemic risk, that is, the stability of financial networks. He is currently writing a book on the subject. In addition to founding the M-Phimac Master program in Financial Mathematics at McMaster, which he continues to direct, he has supervised numerous undergraduate, M.Sc., Ph.D. and Postdoctoral researchers working in financial mathematics.

Ronnie Sircar, Princeton University

Ronnie Sircar is a Professor of Operations Research and Financial Engineering at Princeton University, and is affiliated with the Bendheim Center for Finance, the Program in Applied and Computational Mathematics and the Andlinger Center for Energy and the Environment. He received his doctorate from Stanford University, and taught for three years at the University of Michigan in the Department of Mathematics. He has received continuing National Science Foundation research grants since 1998. He was a recipient of the E-Council Excellence in Teaching Award for his teaching in 2002, 2005 and 2006, and the Howard B. Wentz Jr. Junior Faculty Award in 2003. His research interests center on Financial Mathematics, stochastic volatility models, energy markets, credit risk, asymptotic and computational methods, portfolio optimization and stochastic control problems, utility indifference valuation, and stochastic differential games. He is a co-author of the book "Multiscale Stochastic Volatility for Equity, Interest-Rate and Credit Derivatives", published by Cambridge University Press in 2011.

Steven Shreve, Carnegie Mellon University

Steven Shreve is the Orion Hoch and University Professor of Mathematics at Carnegie Mellon University, where he co-founded the CMU Master's degree in Computational Finance, now in its 19th year, with campuses in New York and Pittsburgh. Shreve received his MS in electrical engineering and his PhD in mathematics from the University of Illinois.

Shreve's book "Stochastic Calculus for Finance" won the 2004 Wilmott award for "Best New Book in Quantitative Finance." Shreve is co-author of the books "Brownian Motion and Stochastic Calculus" and "Methods of Mathematical Finance," advisory editor of of journal "Finance and Stochastics," and past-President of the Bachelier Finance Society. He has published over forty articles in scientific journals on stochastic calculus, stochastic control, and the application of these subjects to finance, including the effect of transaction costs on option pricing, the effect of unknown volatility on option prices, pricing and hedging of exotic options, and models of credit risk.
Zhiliang Ying, Columbia University

Zhiliang Ying is a Professor of Statistics in the Department of Statistics, Columbia University. He received his Ph.D from Columbia University in 1987, with Tze Leung Lai as his doctoral advisor. He was the Director of the Institute of Statistics at Rutgers University from 1997 to 2001. His wide research interests cover Survival Analysis, Sequential Analysis, Longitudinal Data Analysis, Stochastic Processes, Semiparametric Inference, Biostatistics and Educational Statistics. He is a co-editor of Statistica Sinica and has been Associate Editor of JASA, Statistica Sinica, Annals of Statistics, Biometrics, and Lifetime Data Analysis. Ying has supervised, collaborated with and encouraged many researchers. He has written or co-authored more than 100 research articles in professional journals.

Jonathan S. Sokobin, FINRA

Jonathan S. Sokobin, Chief Economist and Senior Vice President at FINRA, oversees the Office of the Chief Economist. In this role, he works closely with the Office of General Counsel and other departments in developing new rules, and analyzing the regulatory impact, including costs and benefits, of existing and potential rulemakings. He leads a team of researchers who gather and analyze data on securities firms and markets in order to inform policymaking at FINRA. Previously, Mr. Sokobin was Acting Deputy Director, leading the Research Center in the Office of Financial Research at the U.S. Treasury Department. He joined the U.S Treasury Department in 2011 as Chief of Analytical Strategy in the Office of Financial Research. Prior to joining the Treasury Department, Mr. Sokobin was Acting Director of the SEC's Division of Risk, Strategy, and Financial Innovation. He joined the SEC staff in 2000 and held various positions, including Deputy Chief Economist and Director of the former Office of Risk Assessment. From 1998 to 2000, he was a Senior Research Fellow at the SEC. Mr. Sokobin began his career as a member of the faculty of the Cox School of Business at Southern Methodist University. He received his Ph.D. and MBA in finance from the Graduate School of Business at the University of Chicago, and his bachelor's degree in economics from the Ohio State University.