

IP1**Games with Exhaustible Resources**

We study N-player repeated Cournot competitions that model the determination of price in an oligopoly where firms choose quantities. These are nonzero-sum (ordinary and stochastic) differential games, whose value functions may be characterized by systems of nonlinear Hamilton-Jacobi-Bellman partial differential equations. When the quantity being produced is in finite supply, such as oil, exhaustibility enters as boundary conditions for the PDEs. We analyze the problem when there is an alternative, but expensive, resource (for example solar technology for energy production), and give an asymptotic approximation in the limit of small exhaustibility. We illustrate the two-player problem by numerical solutions, and discuss the impact of limited oil reserves on production and oil prices in the duopoly case. Joint work with Chris Harris (Cambridge University) and Sam Howison (Oxford University).

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IP2**Self-exciting Corporate Defaults: Contagion vs. Frailty**

Why do corporate defaults cluster? This paper explores the role of contagion, by which the default of a firm has a direct impact on the conditional default rates of the surviving firms, channeled through the complex web of contractual relationships in the economy. We develop filtered maximum likelihood estimators and goodness-of-fit tests for point processes to measure the additional impact of contagion on default rates, over and beyond that due to firms' exposure to observable or unobservable (frailty) risk factors. For U.S. firms during 1970–2006, we find strong evidence that contagion represents a significant additional source of default clustering.

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IP3**Jump-Diffusions and Credit Modelling (Theoretical Models and Practical Implications)**

In this talk we discuss qualitative and quantitative approaches to modelling credit risk and credit events. In particular, we present a view from the trenches of the developing credit crisis.

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IP4**Seasonal and Stochastic Features in Commodity Markets**

After reviewing some of the unique features of commodity markets, we will propose a new model for the dynamics of forward curves. Instead of using the commodity spot price as the first state variable, like in the existing literature, we argue instead that the average value of all liquid forward

contracts is a much better candidate. It is devoid of seasonality and conveys a more robust representation of the global forward curve, a key economic indicator. The cost-of-carry relationship is extended to account for seasonality and stochasticity and applications to strategic energy commodities are described.

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IP5**Advanced Variational Methods for Option Pricing**

This talk will be a review of the possibilities of numerical variational methods such as the Finite Element Method for the partial differential equations of finance. We are quite aware that deterministic methods for option pricing may be hard to impose considering the wide spread usage of Monte-Carlo simulations. Yet deterministic methods offer several advantages for accuracy and speed of computations in many cases. In finance, the finite element method is better than finite difference and finite volume methods for two reasons: mesh adaptivity and a posteriori error estimates. This is even more so for multidimensional problems. However for dimensions greater than 3 one needs to use sparse grid, a powerful yet hard to implement variational method. In this talk we will compare the Monte-Carlo simulations and the Finite Element Simulations for European and American options, for Greeks, for stochastic volatility models with and without jump processes. Large drift terms, as in the case of Asian options can be handled by the Galerkin-Characteristic method. Finally Calibration is made possible by Dupire's identity which we will show to hold at the discrete level whenever the underlying model is linear. Examples of calibration will be given as well.

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IP6**Stochastic Target Problems with Controlled Loss**

This is a joint work with Romuald Elie and Bruno Bouchard. We consider the problem of finding the minimal initial data of a controlled process which guarantees to reach a controlled target with a given probability of success or, more generally, with a given level of expected loss. By suitably increasing the state space and the controls, we show that this problem can be converted into a stochastic target problem, i.e. find the minimal initial data of a controlled process which guarantees to reach a controlled target with probability one. Unlike the existing literature on stochastic target problems, our increased controls are valued in an unbounded set. In this paper, we provide a new derivation of the dynamic programming equation for general stochastic target problems with unbounded controls, together with the appropriate boundary conditions. These results are applied to the problem of quantile hedging in financial mathematics, and are shown to recover the explicit solution of Follmer and Leukert.

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IP7**Title Not Available at Time of Publication**

Abstract not available at time of publication.

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IP8**On the Information Content of Option Prices**

It is well known that the market price of a standard option reflects the risk-neutral mean of its path-independent payoff. It is less well known that this same option price also reflects the risk-neutral mean of various path-dependent payoffs. We give several examples of such payoffs which together suggest that option prices convey much more information than one might initially expect.

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IP9**Title Not Available at Time of Publication**

Abstract not available at time of publication.

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IP10**Title Not Available at Time of Publication**

Abstract not available at time of publication.

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CP1**A Profitable Risk Management Despite Transaction Cost**

We present a new method of profitable investment strategy for portfolio risk management despite transaction cost. Moreover, we implement a rule based expert system for the real-time financial decision making process by using the power of spectral analysis and learning algorithm. Our empirical results show that it is possible to outperform the market for a large data set from S&P 500 index.

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CP1**Gamma Expansion of the Heston Stochastic****Volatility Model**

Based on the squared Bessel bridge decomposition of Pitman and Yor (1982), the integral of the variance process $\int_0^t V_s ds$ conditional on the endpoints can be simulated by generating three independent random variables, each of which can be represented by an infinite series using elementary random variables such as gamma or Poisson. This leads to an efficient simulation scheme improving the exact method of Broadie and Kaya (2006).

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CP1**The Inductive Generation of the Volatility Smile Models**

Volatility of the European-type options depends on their strike and maturity. The authors suppose the volatility smile models based not only the expert knowledge, but also on the measured data. The model generation algorithm was proposed. It generates volatility models of the optimal structure inductively using implied volatility data and expert considerations. The models satisfy expert assessments. The Brent Crude Oil option was considered as an example. The project was supported by RFBR, 07-07-00181.

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CP1**Price Error Sensitivity to the Implied Volatility Estimation**

Numerous explanations for the volatility smile/skew phenomenon and extensions of, or alternatives to, the Black-Scholes model, have been offered in the literature. The inconsistencies between the alternative models and data make it worthwhile to re-think the well-known Black-Scholes model and the cause of its smile/skew phenomenon. Though it has been conjectured that the presence of measurement error can be of substantial impact on the implied volatility estimation, existing research only explains why the curve of implied volatility is non-flat and fails to explain why it exhibits a smile/skew shape. In this paper, I use the relation between option vega and its moneyness to rigorously demonstrate that price error alone can produce volatility smile/skew phenomenon under the Black-Scholes assumptions, thus conclude that volatility smile/skew phenomenon does not necessarily violate the Black-Scholes Model. I further show that implied volatilities from highest vega options outperform at-the-money implied volatilities in terms of forecasting ability, especially for long forecasting horizon, both from theoretical and empirical perspectives.

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CP1**Series Expansion of the Sabr Joint Density**

In this work, we give an accurate analytical solution of the joint transition probability of the SABR stochastic volatility model by solving the density PDE asymptotically. By construction, we have bivariate normal distribution to leading order which corresponds to the normal-normal dynamics. We further derive distribution formulas up to second order in terms of the same bivariate normal but decayed by polynomials of the state variables. Finally the convergence of series expansion is discussed.

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CP2**An Investment Strategy That Dominates the Dynamic Mean-Variance Policy**

Time consistency is indispensable in dynamic portfolio selection, which requires that any tail-subsequence of the overall policy be also optimal for the truncated problem with the remaining time periods. We prove in this paper that the discrete mean-variance formulation is not time-consistent. By allowing investors to withdraw money out of investment under certain circumstances, we can construct a dominating policy, which replicates the optimal mean-variance pair and derives positive dollar value with positive probability.

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CP2**Finite Horizon Optimal Investment and Consumption with Transaction Costs**

This paper concerns optimal investment and consumption decision of a CRRA investor who faces proportional transaction costs and finite time horizon. It is a singular stochastic control problem and two free boundaries which stand for the optimal trading strategies are involved. We present an analytical approach to analyze the behaviors of the free boundaries. Our approach is essentially based on the connection between singular control and optimal stopping, which is first revealed to the present problem.

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CP2**Cardinality Constrained Mean-Variance Dynamic Portfolio Selection**

Often due to the management fee charged for investing in risky assets, investors do not always invest in risky assets in all time periods. Motivated by this consideration, this paper considers the time cardinality constrained mean-variance dynamic portfolio selection problem (TCCMV) in which the number of time periods where investment in risky assets is allowed is limited and derives the optimal policy for both TCCMV problem and the dynamic portfolio selection problem with management fee.

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CP2**Portfolio Selection Using Tikhonov Filtering of the Covariance Matrix of Stock Returns to Reduce Noise**

Markowitz's portfolio selection problem chooses weights for stocks in a portfolio based on an historical covariance matrix for stock returns. Our study proposes to remove noise in the covariance matrix using a *Tikhonov* filter function. Experiments using NYSE stock return data from 1985 to 2007 show that *Tikhonov* filtering estimates the covariance matrix better than methods of Plerou, who suggests truncating the smallest eigenvalues, and Bengtsson, who decreases small eigenvalues at a single rate.

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CP2**Optimal Portfolio Selection with Markov Switching Volatility**

The stock price processes are governed by stochastic differential equations where volatilities are stochastic and scheme switching, i.e., driven by a finite-state Markov chain. Investors can observe the stock prices only. We study its discretized model which is a discrete time hidden Markov process. The objective is to control trading at each time step to maximize an expected utility from terminal wealth. Exploiting dynamic programming techniques, we derive an approximate optimal trading strategy that results in an expected utility function close to the optimal value function. Necessary filtering and forecasting techniques are devel-

oped to compute the near optimal trading strategy.

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CP3

An Optimal Control Problem in Hedging a Portfolio of Collateralized Mortgage Obligations.

Collateralized Mortgage Obligations (CMO) can exhibit different degrees of cash flow variability depending on tranche structure and realized prepayment speeds. In order to have a meaningful comparison across structures and collateral types an Option-Adjusted Spread (OAS) methodology is typically used. While OAS provides a meaningful improvement to yield to maturity for CMO, it does not fully account for embedded optionality. We introduce a related methodology which significantly improves valuation metric for CMOs. In this method, the construction of the optimal hedging policy is considered as an essential part of the valuation procedure. To ensure the convergence of the resulting ill-conditioned optimization problem, the standard Tikhonov type regularization technique is applied. The developed numerical algorithm is based on the combination of the the Broyden-Fletcher-Goldfarb-Shanno (BFGS) and Newton methods. The convergence of this method and the stability of the underlying control optimization problem are discussed. The numerical results on the hedging of the portfolios of CMO and European swaptions based on Monte Carlo simulation are presented.

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CP3

Generalized Beta Regression Models for Random Loss-Given-Default

We propose a new framework for modeling systematic risk in Loss-Given-Default (LGD) in the context of credit portfolio losses. The class of models is very flexible and accommodates well skewness and heteroscedastic errors. The quantities in the models have simple economic interpretation. Inference of models in this framework can be unified. Moreover, it allows efficient numerical procedures, such as the normal approximation and the saddlepoint approximation, to calculate the portfolio loss distribution.

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CP3

Incorporating Risk Aversion and Model Uncertainty into Structural Models of Default

Using indifference pricing with exponential utility, we determine corporate bond prices and CDS spreads. Leung, Sircar and Zariphopoulou (2007) recently introduced a structural model, in which default of the reference entity is triggered by a credit worthiness index correlated to its stock price. In an unrelated paper, Uppal and Wang (2003) study portfolio optimization when model parameters are unknown. We combine these two approaches and derive some analytical and numerical results.

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CP3

Fast Valuation of Forward-Starting Basket Default Swaps

We develop a fast approximation method for Forward-starting Basket Default Swaps (FBDS) based on the conditional independence framework. The method converts the pricing of a FBDS to an equivalent basket default swap pricing problem and combines Monte Carlo simulation with an analytic approach to achieve an effective method. Numerical results demonstrate the accuracy and efficiency of the proposed hybrid method.

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CP3

Comparison of Credit Default Models

Similarities and differences in the structural (value-of-firm), copula and intensity models of credit default will be examined. A complete description of the relationship of the default probability of a single firm and its default barrier will be given in the structural model. We will then outline how default correlation between two firms is naturally included in these structural models and derive the joint default probability of the firms in this context. Comparisons will be made with the joint default probabilities obtained from copula and intensity models in the context of tail dependence (independence of extreme events), calibration to first-to-default credit default swaps (FtD CDS) and the distribution of time between defaults. This is joint work with

students Junming Huang, Bo Shi and Lung Kwan Tsui.

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CP4

Adaptive and High-Order Numerical Pricing of American Options

We present space-time adaptive and high-order methods for pricing American options. Both finite difference and finite element methods are considered for the space discretization. The high-order discretization in space is based on optimal finite element collocation methods. To control the space error, we use adaptive gridpoints distribution based on an error equidistribution principle. Numerical examples show that our methods converge fast and provide accurate options prices, the Greeks, and early exercise boundaries.

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CP4

Latin Hypercube Sampling with Dependence and Applications in Finance

In Monte Carlo simulation, Latin hypercube sampling (LHS) [McKay et al. (1979)] is a well-known variance reduction technique for vectors of independent random variables. The method presented here, Latin hypercube sampling with dependence (LHSD), extends LHS to vectors of dependent random variables. The resulting estimator is shown to be consistent and asymptotically unbiased. For the bivariate case and under some conditions on the joint distribution, a central limit theorem together with a closed formula for the limit variance are derived. It is shown that for a class of estimators satisfying some monotonicity condition the LHSD limit variance is never greater than the corresponding Monte Carlo limit variance. In some valuation examples of financial payoffs, when compared to standard Monte Carlo simulation, a variance reduction of factors up to 200 is achieved. LHSD is suited for problems with rare events and for high-dimensional problems, and it may be combined with Quasi-Monte Carlo methods.

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CP4

Integral Equations Arising from the First Passage Time Problem Via Martingale Methods

One of the main tools in tackling the First Passage Time problem for Brownian motion is the integral equations formulation of the problem. In this talk I will construct a new generalized class of integral equations using a martingale approach. This class contains previously known Volterra

equations of the first kind such as Peskir's equations. Finally, for a subclass of equations, I will investigate sufficient conditions for the existence of a unique continuous solution.

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CP4

Pricing and Hedging American-style Options: A Simple Simulation-based Approach

This article presents a simple yet powerful approach for approximating the values of prices and hedging parameters for American-style options, which is primarily based upon the well-known LSM algorithm. This approach is readily applicable in path-dependent and multifactor situations where traditional lattice techniques cannot be used. We illustrate this with several examples, including an American max-call option on multiple assets, an exotic American-Bermuda-Asian option, and an American option when the underlying follows a jump-diffusion process.

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CP4

An Asymptotically Optimal Strategy in Change Point Detection and Identification and Its Applications in Finance

We consider a fusion of the quickest detection and hypothesis testing, both of which are commonly used in economics and finance. Suppose the distribution of a sequence of i.i.d. random variables changes suddenly at some unobservable time to one of finitely many distinct alternatives, then one needs to detect and identify the change at the earliest. We propose an asymptotically optimal strategy under the Bayesian and the fixed-error formulations and discuss its applications in finance.

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CP5

Towards Optimizing A Passive Investment Portfolio in the Presence of Taxes

Determining the optimal continuous time rebalancing strategy for maximizing a taxable portfolios utility at a

given later time corresponds to the computationally impossible task of solving an infinite dimensional PDE. Worse, even very simple optimal discrete time rebalancing problems quickly become computationally infeasible high dimensional PDE. We show, however, that we can determine the optimal rebalancing of a taxable portfolio with any cost basis history while still allowing for continuous time loss harvesting in the future. This involves solving a relatively low dimension PDE with an oblique reflecting boundary condition.

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CP5

Latent Space Model for Mining Financial Data

From one perspective, latent space model originates from Random Graph Model. From another perspective, it is based on MDS(Multi-dimensional Scaling). So this method combines the advantages of these two methods. LSM is an effective way to do classification and clustering. Using this method, we can understand the underlying relationship of complex data. In this talk, we'll show you examples of mining financial data and how to make stocks analysis with latent space method.

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CP5

Dynamical Optimal Portfolio Rules When Equity Returns Are Stochastic

In this talk, we consider the problem of optimal portfolio for an investor to maximize her terminal utility of wealth with a finite time horizon when facing the same opportunity set as in the case of Merton's "asymptotic 'normal' price level' hypothesis within the continuous time framework. That is, there are two assets, one risky and one riskless. The riskless asset has a constant rate of return. The risky asset follows the "asymptotic 'normal' price level' hypothesis. The "asymptotic 'normal' price level' hypothesis assumes a long term growth rate of the price of the risky asset independent of the present level which may agree well with the empirical evidence of many independent studies such as that of Siegel (1994) where the history of stock market in the last one hundred years has been analyzed and a long term growth rate of stocks discerned. The utility function we use will be the HARA-Class (Hyperbolic absolute risk aversion). The analytic solutions for the portfolio rule and expected-utility functions are found. The solutions can be classified as *well-behaved* and *nirvana* solutions. In latter case, investor can attain nirvana in a long but finite time horizons through optimal trading strategies, a phenomenon first discovered for a different model in Kim and Omberg (1996). The nirvana is defined as maximum expected utility for utility function which is bounded, and ∞ expected utility for utility function which is not bounded above. The solutions help answer various questions regarding dynamic nonmyopic behaviour such as (i) when an investor holds more or less risky asset; (ii) whether an investor hedges against or speculates on the risky premium uncertainty; (iii) when an investor is long or short the risky asset.

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CP5

On the Cost of Poor Volatility Modeling: The Case of Cliquets

We have conducted pricing and hedging experiments in order to check whether simple stochastic volatility models are capable to capture the forward volatility and forward skew risks correctly. As a reference we have used the Bergomi model that treats these risks accurately per definition. Results of our experiments show that the cost of poor volatility modeling in the Heston model, the Barndorff-Nielsen-Shephard model and a Variance-Gamma model with stochastic arrival is too high when pricing and hedging cliquet options.

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CP6

Boundary Conditions In Option Pricing

Abstract not available at time of publication.

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CP6

Refined and Enhanced Fast Fourier Transform (FFT) Techniques, with Applications to the Valuation of Single and Double Barrier Options

We explain how Carr's randomization approximation can be applied to the problem of pricing a knock-out option with one or two barriers. It results in a backward induction procedure, each of whose steps can be reduced to computing a sequence of Fourier transforms and inverse Fourier transforms. However, the numerical calculation of Fourier transforms via FFT may lead to significant errors, which are often hard or impossible to control when standard FFT techniques are used. We present a new approach to implementing FFT techniques that allows one to control these errors, resulting in fast and accurate algorithms for pricing single and double barrier options

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CP6

On the Numerical Evaluation of Option Prices in the Variance Gamma Model

Because the pricing equations in Levy models contain integrals it is difficult to develop rapid numerical methods for solving them. Although the integrals are not periodic, the standard methods use the FFT, and therefore require large computational regions to ensure accuracy. In earlier work we developed efficient methods for pricing options in the Merton and Kou models. The methods rely on the fact that in those models the density functions satisfy ordinary or partial differential equations, so differential methods can be used to evaluate the integrals. In this talk we present efficient numerical methods for pricing options in another Levy model, the Variance Gamma model.

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CP6

Nonlinear Filtering Of Ito-Levy Stochastic Differential Equations With Discontinuous Observations And Applications to Finance

We study the nonlinear filtering problem for jump-diffusion processes. The equation of the optimal filter is derived for the case when the observations are discontinuous. A proof of uniqueness of the solution is presented. An application of this problem to the estimation of the asset price volatility is discussed.

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CP6

FFT-Based Option Pricing under Mean-Reverting Jump-Diffusion Processes

Energy commodities, such as oil, gas and electricity, exhibit high volatilities, have sudden price jumps and tend to revert to a long run equilibrium. We develop an FFT-based method for valuing path-dependent contingent claims written on mean-reverting processes with jumps. The method is efficient as European options can be priced using a single time-step to obtain option values for a range of spot prices. Furthermore, Bermudan options do not require time-stepping between monitoring dates and the method can be readily extended to the multi-asset framework. We carry out several pricing experiments on European, American styled swing and two-asset spread options.

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CP7

On the Measurement of Credit Risk: A New Geometric Approach

This paper presents a complementary technique for the empirical analysis of risk and bankruptcy using financial ratios. Within this framework, we propose the use of a new measure of risk, which is Share Risk measure, and provide evidence of the extent to which changes in values of this index are associated with changes in each axis values and how this may alter our economic interpretation of changes in the patterns and direction of risk. Solving some methodological problems concerned using financial ratios such as ratio outliers, non-proportionality, non-asymmetry, non-scalability and non-normal distribution are illustrated. Then results of Multiple Discriminant Analysis (MDA) and Genetic Programming (GP) are compared for common and modified ratios and higher accuracy achieved.

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CP7

Efficient Estimation of Credit Risk for Large Portfolios

We present an efficient analytic approach for estimating credit risk of fixed income portfolios with many obligors. Large real world uncertainties lead us to choose a parsimonious modeling framework that avoids brute force Monte Carlo simulation. We solve an aggregation problem of summing up correlated random variables, as well as an allocation problem of providing an additive decomposition of total portfolio risk to atomic portfolio subcomponents.

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CP7

Credit Derivative Modelling with Jump Hazard Process

We introduce a model for Credit Default Swaps (CDS) and Collateralized Debt Obligations (CDO). We consider an intensity based approach using Levy processes to pricing these products. We show that with a bottom-up approach we can create default correlation between firms, and are able to fit the market observed loss distribution. The models are tractable, and are easily calibrated to quoted index CDO tranches for several maturities. Furthermore, the

pricing is consistent with the single name default probabilities.

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CP7

Basle II Capital Requirement Sensitivity to the Definition of Default

The paper is motivated by a disturbing observation according to which the outcome of the Basle II regulatory capital formula significantly depends on the definition of default used to measure the probability of default (PD) and the loss given default (LGD) parameters. Basle II regulatory capital should estimate with certain probability level unexpected credit losses on a banking portfolio and so it should not depend on a particular definition of default that does not change real historical and expected losses. We provide an explanation of the phenomenon based on the Merton default model and test it using a Monte Carlo simulation. Moreover we shall develop an analytical method to model LGD unexpected risk and to combine it with the PD unexpected risk. The developed formula and in particular its simplified version could be used to improve the current regulatory formula. The formula at the same time provides a different insight into the issue of regulatory capital sensitivity on the definition of default. Finally we perform a structural model based simulation to test the hypothesis according to which scoring functions developed with a soft definition of default provide weaker predictive power than the ones developed with a hard definition of default.

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CP8

Integrating QuantLib and *Mathematica*

The open-source mathematical finance library of C++ code known as QuantLib (quantlib.org) and the commercial computer algebra application *Mathematica* (www.wolfram.com) possess complementing capabilities. QuantLib provides a variety of software objects and numerical methods for pricing financial instruments, while *Mathematica* provides a general purpose modeling, visualization, and software development environment with interfaces to curated financial data. Making the functions of the object-oriented library available from within the *Mathematica* kernel via the MathLink API involves strategic function choices on the C++ side and careful user interface development on the *Mathematica* side.

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CP8

Optimal Acquisition of a Partially Hedgeable House

We consider the problem of the optimal time to purchase a house by a risk-averse investor in a complete financial market, whose objective is to maximize expected (CARA) utility from terminal wealth. The house purchase is financially attractive. However its value is only partially correlated with financial markets and, therefore, house price

risk cannot be perfectly hedged, which provides an incentive to delay purchase. We fully characterize the problem, generate numerical solutions for different parameters, and study the trade-off between the conflicting incentives.

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CP8

Modeling Subordinated Stochastic Processes with Student's t and Generalized Secant Hyperbolic Distribution Increments: Empirical Study of Speculative Energy Markets

Energy returns observed in speculative markets are modeled as Subordinated Stochastic Processes given their complex market infrastructure, which is highly susceptible to real time environmental and geopolitical shocks. Independent increment assumption is compared between Student's t and Generalized Secant Hyperbolic distribution. GSHD approaches uniform and Cauchy distributions in its limits; it is infinitely divisible and for certain ranges of shape is self-decomposable. Deriving the densities of corresponding directing processes, we propose signal detection for change in risk.

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CP8

Finding Associative Price Patterns in Stock Data

This paper proposes a statistical computational method to determine whether or not associative price patterns exist in financial time series such as in stock price series. The problem of finding patterns in financial time series have been tackled by systematical observations, statistical analysis or by the use of artificial intelligence techniques. However, the emphasis is more on finding pattern in data rather than finding associations between patterns. Given that patterns in time series may overlap or be scattered within a series, the discovering of pattern association has not receive much attention. The paper proposes a technique to find elementary patterns in financial time series. Based on it, a sequence of patterns can then be constructed for the original time series. Using the idea of residual analysis, we show how we can conclude that an associative relationship exists between two patterns.

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CP8

Random Search Learning in Double Auction Markets

Double auction markets are the principle mechanism of exchange in many financial markets. In this paper an evolutionary random search algorithm is proposed for learning in double auction markets where the agents are either

members of the population of sellers or the population of buyers. The output of strategy of a buyer is the price that he bids to buy and the output of strategy of a seller is the price that he offers to sell. Both groups of players try to learn the optimum bid/offer that maximizes their individual gain in the next round of the game. Comparison of performance of this algorithm to a genetic learning algorithm previously used for the same purpose, shows much faster convergence to a market equilibrium.

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MS1

A Constructive Approach to Local Volatility Models

The traditional approach to local volatility models uses the Fokker-Planck or Kolmogorov forward equation to connect the one-dimensional marginal distributions and the infinitesimal generator of a diffusion process. In this talk, we will offer a construction approach to local volatility models which avoids the use of PDEs. This approach has the advantage that it extends naturally to handle a number of path-dependent options, and it also allows for the relaxation of the technical conditions which seem to be necessary for a PDE-based argument.

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MS1

Short maturity asymptotics for fast mean-reverting stochastic volatility models

Implied volatility skew for models with fast mean-reverting stochastic volatility is well understood using singular perturbation methods (Fouque-Papanicolaou-Sircar, CUP 2000). Here, we consider a regime where SV is fast mean reverting and maturities are short. We derive a large deviation principal for the Heston model via an explicit computation of moment generating functions. An alternative approach using homogenization of HJB equations for more general SV models will also be presented.

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MS1

Swap Rate Variance Swaps

We replicate a variance swap defined on a swap rate, using a static payoff and a dynamic strategy in swaps. Two novel features arise in the rates context: the dynamically

traded asset is nonlinear on the underlying rate, and the dynamic reinvestment rate is stochastic. These generate additional (variance related) gains, requiring an appropriate static payoff. We characterize it as the solution of an ordinary differential equation. Accuracy of the replication is confirmed empirically.

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MS1

Local Volatility Dynamic Models

We discuss the characterization of arbitrage free dynamic stochastic models for the equity markets with infinite set of basic instruments (European type options). Prices of the financial instruments are represented through local volatility, which is then given dynamics through Ito stochastic differential equation on a Banach space (following the HJM approach). The main thrust of our work is to characterize absence of arbitrage in these models and to parameterize them in a convenient for implementation way.

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MS2

A Unified Framework for Pricing Credit and Equity Derivatives

We propose a model which can be jointly calibrated to the bonds and equity options of the same company. We also use the historical stock price, historical spot rate, and treasury yield curve data as inputs to our model for parameter estimation. We observe that the model implied credit default swap (CDS) spread matches the market CDS spread and that our model produces a very desirable CDS spread term structure. This is striking since without calibrating any parameter to the CDS spread data, it is matched by the CDS spread our model generates using the available information from the equity options and corporate bond markets. We also observe that our model matches the equity option implied volatility surface well. We demonstrate the importance of accounting for the default risk and stochastic interest rate in equity option pricing by comparing our results to Fouque et al. (2003), which proposed a similar modeling framework in the context of stochastic volatility models.

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MS2

Dynamic Hedging of Portfolio Credit Derivatives

We study hedging of index CDO tranches with the underlying CDS index in various aggregate loss models which account for default contagion and spread risk. In partic-

ular, we compare sensitivity-based hedging with hedging strategies based on quadratic risk minimization. Numerical results obtained in models calibrated to ITraxx market data reveal significant differences in the hedge ratios and show, unlike what had been previously suggested in the literature by comparing copula-based models, that hedging strategies are subject to substantial model risk. Finally, we study the empirical performance of various hedging using ITRAXX time series. Our study reveals in particular that delta-hedging of spread risk using the Gaussian Copula model does not appear to be an effective hedging strategy, especially during and after the 2007 subprime crisis.

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MS2

Top-Down Credit Models: Ride with the Top Down

In the top-down approach to multi-name credit modeling, calculation of single name sensitivities appears possible, at least in principle, within the random thinning procedure which dissects the portfolio risk into individual contributions. We make an attempt to construct a practical random thinning framework that enables efficient calculation of single name sensitivities in a top-down framework, and can be extended to valuation and risk management of bespoke tranches, as well as to modelling dynamics of single names in a credit portfolio in a way consistent with a calibrated portfolio-level dynamics.

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MS2

Time Changed Markov Processes in Unified Credit-Equity Modeling

This paper develops a novel class of hybrid credit-equity models with state-dependent jumps, local-stochastic volatility and default intensity based on time changes of Markov processes with killing. We model the defaultable stock price process as a time changed Markov diffusion process with state-dependent local volatility and killing rate (default intensity). When the time change is a Levy subordinator, the stock price process exhibits jumps with state-dependent Levy measure. When the time change is a time integral of an activity rate process, the stock price process has local-stochastic volatility and default intensity. When the time change process is a Levy subordinator in turn time changed with a time integral of an activity rate process, the stock price process has state-dependent jumps, local-stochastic volatility and default intensity. We develop two analytical approaches to the pricing of credit and equity derivatives in this class of models. The two approaches are based on the Laplace transform inversion and the spectral expansion approach, respectively. If the resolvent (the Laplace transform of the transition semigroup) of the Markov process and the Laplace transform of the time change are both available in closed form, the expectation operator of the time changed process is expressed in closed form as a single integral in the complex plane. If the payoff is square-integrable, the complex integral is further reduced to a spectral expansion. To illustrate our general framework, we time change the jump-to-default extended CEV model (JDCEV) of Carr and Linetsky (2006)

and obtain a rich class of analytically tractable models with jumps, local-stochastic volatility and default intensity. These models can be used to jointly price equity and credit derivatives.

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MS3

Mean Reversion and Statistical Arbitrage Strategies in Equities

This talk presents new (and perhaps not so new) models for statistical arbitrage in equities. We shall discuss the concept of market-neutrality, both from the ‘covariance viewpoint’ as well as from the point of view of ETF/sector/market capitalization. We will then present an approach to quantitative equity valuation model based on mean reversion and the corresponding trading signals that derive from such model. Taking into account leverage and targeted volatility, we construct market-neutral portfolios involving a large universe of stocks. We back-test several mean-reversion strategies from January 1996 until December 2007. This approach takes into account transaction costs and, to some extent, trading impact as well. Several versions of the strategy are simulated: for instance, we can compare ‘Markowitz type’ strategies, in which trading is nearly continuous, with strategies in which trading is based on reaching statistical thresholds. We also compare the performance of portfolios constructed via covariance-type methods with ETF-neutral portfolios and we find the former to perform slightly better given the data. The overall picture is an up-to-date view on statistical arbitrage strategies and their historical performance from its inception to the present date.

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MS3

Incorporating Market Impact Costs Into Dynamic Portfolio Optimization

Incorrectly accounting for transaction costs in the portfolio construction process leads to inefficient allocation of capital and loss of performance. In this talk, we show how to integrate a realistic market impact model by using a piecewise linear approximation into an optimization framework that is consistent with quadratic (QP) or second-order cone programming (SOCP), and provide estimates of the resulting approximation error. We describe a simple extension of the model that incorporates the model uncertainty arising from estimation error of the impact model, and illustrate how this framework can be used in dynamic portfolio optimization.

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MS3**High-Frequency Simulation for Dynamic Portfolio Analysis**

The problem of finding an optimal trade schedule for liquidating or accumulating stocks in a portfolio commonly referred to as optimal execution is a subset of the portfolio manager's true problem small delta, continuous trading. Unlike optimal execution, which has a static solution, small delta continuous trading is a dynamic programming problem. Several attempts have been made to simplify this complex multi-dimensional problem to arrive at an analytical solution. An attractive alternative to these approaches is simulation, which requires fewer compromises in assumptions about market impact, expected returns, and risk. The difficulty of writing simulations in this domain is the high degree of CPU and data processing intensity required to achieve accurate results. This presentation will focus on an approach to building computationally efficient simulations for dynamically managing large, complex portfolios.

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MS3**Optimal Rebalancing: A Scalable Solution**

In an idealized world without transaction costs investors would rebalance continually to the optimal weights. In the presence of transaction costs investors must balance the cost of sub-optimality with the cost of restoring the optimal weights. Most investors employ heuristics that rebalance the portfolio as a function of the passage of time or the size of the misallocation. A rebalancing algorithm based on dynamic programming is a mathematically more rigorous approach that allows the investor to determine optimal rebalancing rules; rules which have proven significantly superior to standard industry heuristics. However, this approach requires exponential resources as the number of assets increase, i.e. it suffers from the curse of dimensionality. Applying an adaptation of Markowitz and van Dijk's methodology for dynamic asset allocation under shifting expectations, we present a rebalancing solution that is tractable for a large number of assets and which reduces the costs associated with rebalancing by as much as 20 to 50 percent compared with the standard industry heuristics.

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MS4**Title Not Available at Time of Publication**

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MS4**Direct and Inverse Boundary Crossing Problems for Diffusions: PDEs and Integral Equations**

For a one dimensional diffusion process X , the boundary

crossing problem is, given a boundary $b(t)$, to find the probability distribution $p(t)$ of the first time that X hits b . The inverse boundary crossing problem is, given a probability distribution p , to find a boundary $b(t)$ with hitting distribution equal to p . I will discuss recent work on analytical formulations of these problems in terms of partial differential equations and integral equations.

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MS4**An Integral Equation Approach to a Free Boundary Problem Arising from Mortgage Valuation**

Consider a fixed rate mortgage contract, where the borrower pays continuously an equal amount of payment per unit time and has the right to close the contract by paying off the outstanding loan balance all at once. Then the borrower's optimal financial decision is to invest in the market an amount equal to the loan balance as long as the overall return from the investment is more than enough to cover the cost of subsequent mortgage payments. Here we provide a mathematical model where the optimal prepayment of the mortgage is treated as a free boundary problem. The free boundary is solved using integral equation techniques. In particular, we found lower bound and upper bound of the free boundary which can be used to approximate the true solution. Certain analytical and numerical features of the model will be discussed. Possible applications to related problem will also be discussed.

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MS4**Comparison of Credit Default Models**

Similarities and differences in the structural (value-of-firm), copula and intensity models of credit default will be examined. A complete description of the relationship of the default probability of a single firm and its default barrier will be given in the structural model. We will then outline how default correlation between two firms is naturally included in these structural models and derive the joint default probability of the firms in this context. Comparisons will be made with the joint default probabilities obtained from copula and intensity models in the context of tail dependence (independence of extreme events), calibration to first-to-default credit default swaps (FtD CDS) and the distribution of time between defaults. This is joint work with students Junming Huang, Bo Shi and Lung Kwan Tsui.

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MS5**American Options Under Stochastic Volatility and Jumps**

We consider the problem of pricing an American option when the underlying asset price ‘jumps and has stochastic volatility. An exercise-policy improvement scheme that converts the free-boundary problem into a sequence of fixed-boundary problems is developed to calculate option prices and exercise policies. The scheme monotonically converges for a variety of stochastic volatility models and jump diffusions. With the scheme, we explore the dependency of option pricing on various important parameters to gain insights.

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MS5**Hilbert Transform Approach for Options Pricing**

We present a method based on Hilbert transform for the pricing of a variety of exotic options. The associated Hilbert transform can be approximated highly accurately, with exponentially decaying errors. The discrete approximation can be efficiently implemented using the fast Fourier transform.

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MS5**A Local Discontinuous Galerkin Finite Element Method for Portfolio Optimization Problems with Transaction Costs**

To study a portfolio optimization problem with transaction costs we set up a buy-and-hold problem, which can be transformed into a convection-dominated PDE problem. To solve the problem with high-order numerical scheme and overcome the spurious oscillations, we use the Local Discontinuous Galerkin method and a sequential optimization process to effectively determine the no-trade region. Our error estimate will help stochastic optimization approach by providing reliable benchmarks

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MS5**Markov Chain Approximation on Optimal Portfo-****lio with Subadditive Transaction Cost**

The model to be presented is motivated by optimal portfolio problem with non-zero transaction cost on finite time horizon. The sub-additivity is imposed to transaction cost. The optimal value can be characterized as solution of certain system of quasi-variational inequalities in parabolic type. First, we study the uniqueness of viscosity solutions. The Markov chain approximation for the value function is proposed, which is in turn equivalent to finite difference method. The convergence of Markov chain approximation can be shown by uniqueness of viscosity solutions.

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MS6**A Probabilistic Approach to Inverse Problems in Option Pricing**

We propose a new approach to the model calibration problem, which takes into account the multiplicity of solutions. Starting from a prior distribution on model parameters and a set of observed option prices, we propose a probabilistic construction which yields an arbitrage free pricing rule consistent with these observed option prices. Our approach yields a simple Monte Carlo algorithm for simulating from this posterior distribution, taking into account the value of liquidly traded (“vanilla”) options.

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MS6**Pricing Hybrid Products Under Affine Jump Diffusion Models**

We present an extension of the stochastic volatility equity models by a stochastic Hull-White interest rate component. We place this system of stochastic differential equations in the class of affine jump diffusion - linear quadratic jump-diffusion processes (Duffie, Pan and Singleton, Cheng and Scaillet) so that the pricing of European products can be efficiently done within the Fourier cosine expansion pricing framework. We also apply the model to price some hybrid structured derivatives, which combine the different asset classes: equity and interest rate.

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MS6**Maximum Likelihood Estimation of Parameters of Diffusion Processes by Numerical Solution of the Fokker-Planck Equation**

Derivative pricing models generally assume that changes in state variables are described by stochastic differential equations. Estimating the parameters of these models is important for both valuation and hedging. Maximum likelihood estimation has attractive statistical properties, but the transition density is available analytically for only a few special cases. In principle, it can be estimated by numerically solving the Fokker-Planck equation. We explore the feasibility of obtaining maximum likelihood estimates from this numerical solution.

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MS6**Pricing Options under Stochastic Volatility Models**

A generalization of the Black-Scholes model is obtained by let the volatility also to be stochastic. As no closed-form formula exists for American options one needs to use numerical methods. A common approach is to derive a two-dimensional parabolic partial differential equation (PDE) for the price. We consider accurate discretizations for this PDE and fast solution procedures for the resulting systems of equations.

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MS7**Optimal Investment Strategies Under Bounded Risk**

We consider the problem of maximizing expected utility from terminal wealth under an additional risk constraint. In the case of a complete market and risk measures of a certain type (e.g. the entropic risk measure), explicit results can be given. For the general case of an arbitrary convex risk measure, the problem gets more involved. We discuss the limitation of Lagrange Duality, propose Fenchel

Duality instead and solve the problem for special cases.

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MS8**True Upper Bounds for Bermudan Products Via Non-nested Monte Carlo**

We present a non-nested Monte Carlo procedure for computing true upper bounds for Bermudan products, given an approximation of the Snell envelope. The pleonastic ‘true’ stresses that, by construction, the estimator is biased above the Snell envelope. The key idea is a regression estimator for the Doob martingale part of the approximative Snell envelope, which preserves the martingale property. The so constructed martingale can be employed for computing tight dual upper bounds without nested simulation. Numerical experiments indicate the efficiency of the proposed algorithm.

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MS8**Spatial Risk and Temperature Derivatives**

Temperature derivatives may be used to hedge weather-linked risk, which is spatially distributed. In this presentation we construct optimal positions in temperature futures from available market-traded contracts to hedge the spatial risk. Temperature dynamics are modelled by a stochastic differential equation with spatial dependence. Optimal positions in market-traded futures minimizing the variance are calculated. Examples with numerical simulations based on a fast algorithm for the generation of random fields are presented.

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MS8**Importance Sampling and Interacting Particle Systems for the Estimation of Markovian Credit Portfolios Loss Distribution**

We compare two variance reduction methods for computing by simulation portfolio loss distributions in Markovian intensity models of credit risk: Importance Sampling and Interacting Particles approaches. We describe in detail both method, and we highlight their fundamental differences. We then proceed to a detailed comparative case

study based on benchmark numerical experiments.

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MS8

How to Simulate a Levy-driven SDE If You Must

We present a new algorithm for weak approximation of stochastic differential equations driven by infinite activity Levy processes. The method is based on adaptive non-uniform discretization based on the jump times of the driving process. Our technique avoids the costly simulation of the increments of the Levy process and in many cases achieves better convergence rates than the traditional schemes with equal time steps. Applications to option pricing and market scenario simulation will also be discussed.

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MS9

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MS9

Pi Options: From American to Russian, and look-back.

We consider a discretionary stopping problem that arises in the context of pricing a class of perpetual American-type call options, which include the perpetual American, Russian and lookback-American call options as special cases. We solve this genuinely two-dimensional optimal stopping problem by means of an explicit construction of its value function. In particular, we fully characterize the free-boundary that provides the optimal strategy, and which involves the analysis of a highly non-linear ordinary differential equation (ODE). It turns out that determining this free-boundary relies on the so-called transversality condition in a rather non-trivial way.

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MS9

Optimal Switching Problems with Hidden Markov Chains

We study finite horizon optimal switching problems for hidden Markov chain models under partially observable Poisson processes. The controller possesses a finite range of strategies and attempts to track the state of the unobserved state variable using Bayesian updates over the discrete observations. Such a model has applications in economic policy making, staffing under variable demand levels and generalized Poisson disorder problems. We show regularity of the value function and explicitly characterize an optimal strategy. We also provide an efficient numerical scheme and a computational example. In the last part of the talk I will discuss a related problem in the context of inventory management with incomplete information.

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MS9

Analysis of the Optimal Exercise Boundary of American Options for Jump Diffusions

In this paper we show that the optimal exercise boundary/free boundary of the American put option pricing problem for jump diffusions is continuously differentiable (except at the maturity). We also show that the boundary is infinitely differentiable under a regularity assumption on the jump distribution.

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MS10

Inverse Stochastic Dominance Constraints

We consider optimization problems with second order non-linear stochastic dominance constraints formulated as a relation of Lorenz curves. The relation is characterized in terms of rank dependent utility functions, which generalize Yaari's utility functions. We develop optimality conditions and prove that Lagrange multipliers associated with these constraints can be identified with rank dependent utility functions. Furthermore, we demonstrate that mean-risk models with law invariant coherent risk measures appear as dual optimization problems to the problems with stochastic dominance constraints. Cutting plane methods for solving these optimization problems and their convergence will be discussed as well.

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MS10**Conditional Mean-Conditional Variance Portfolio Selection Models**

We formulate conditional counterparts of Markowitz mean-variance portfolio selection models. If the returns have a logconcave probability distribution, then the conditional variance has a monotonicity property. We also specialize the models for the case of joint normal distribution and discuss the calculation of the efficient frontier. Comparison of the results to those obtained by Markowitz models will be presented. The results are in close connection with VaR and CVaR.

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MS10**Optimization with Stochastic Dominance Constraints**

We discuss new optimization models involving stochastic dominance constraints, and present optimality and duality theory. In particular, we show that the Lagrange multipliers can be identified with utility functions. Next, we introduce a stochastic dynamic optimization problem, where risk aversion is expressed by a multivariate stochastic dominance constraint. We develop necessary and sufficient conditions of optimality for convex stochastic control problems with the new ordering constraint and we derive an equivalent control problem featuring implied utility functions. Furthermore, we prove the existence of an optimal random discount sequence and we present a version of the maximum principle for the problem with discounted dominance constraints. Finally we discuss ideas of numerical methods for solving problems with stochastic dominance constraints.

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MS11**Efficient Monte Carlo Methods for Financial Market Model Calibration**

In recent years optimization problems have gained increasing importance in the finance sector. We focus on the numerical solution of a stochastic model for option prices. In particular, we are concerned with the calibration of these models to real data, which leads to large scale optimization problems. As the model structure is often not fixed,

stochastic differential equations in a Monte Carlo framework are a good choice. However, it is well known that Monte Carlo requires a high computational effort. Thus our focus will be on the introduction of several techniques to reduce the complexity of this problem.

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MS11**Parameter Identification in Financial Market Models with a Feasible Point SQP Algorithm**

For many financial market models the projection of the iterates of a calibration algorithm onto the feasible set can be computed either analytically or via the numerical solution of a small auxiliary problem. For the case of Heston's stochastic volatility model this projection can for example be obtained by solving a semidefinite programming problem. Combining the derived SDP-projection with a feasible point SQP algorithm and Gauss-Newton approximation of the Hessian leads to an efficient method which allows to quickly calibrate the model in less than one second on a desktop PC. Furthermore, we present numerical results for a jump diffusion model as well as a regularization technique that stabilizes the calibration if the model parameters are time-dependent.

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MS11**A Generalized Dupire Formula and its Stable Estimation**

Exponential Levy models are known to be capable of reproducing observed implied volatility surfaces well for one maturity, but to have some problems when a whole range of maturities shall be fitted. One way to overcome this drawback and to introduce more flexibility in the model is by allowing for a state and time dependent time change of the driving stochastic process. In the classic model of Black and Scholes this procedure leads to the well-known local volatility model. Now in order to calibrate the market model to the implied volatility surface one needs to compute the time-change, which for the local volatility model can be done using the famous Dupire formula. In this talk we consider the problem of identifying the time change in a more general Levy market setting and discuss some regularization schemes to tackle its ill-posedness. In particular we also derive a Dupire-like formula for the generalized model and propose a possible method to stabilize its estimation.

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MS11**Gradient Computation via Adjoint in Model Calibration**

The calibration of mathematical models for financial markets is a special class of optimization problems. We review some of the most successful optimization methods in order to solve these problems numerically. Special emphasis is given on the fast computation of gradients, where the

adjoint calculus provides a basis for highly efficient algorithms. This technique is applicable to models using partial differential equations as well as stochastic differential equations and also difference equations. We give some results in the context of calibrating pricing models for derivatives.

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PP0

Option Pricing in the Presence of Random Arbitrage Return

We consider option pricing problems when we relax the condition of no arbitrage in the Black Scholes model. The derived pricing equation is in the form of Stochastic Partial Differential Equation (SPDE). We used Karhunen-Loève expansion to approximate the stochastic term, and the numerical solution of the SPDE is computed using Finite Element Method.

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PP0

Networked Ising-Sznajd Models and the Stock Markets

The Ising-Sznajd spin model is applied to analyze the phenomena of heavy fall and/or sudden rise in stock prices. We consider the problem in connection with some special networks such as Watts-Strogatz model, Erdős model, and Barabási model and so on. We applied Onsager's calculation of the partition function of the 2-dimensional Ising model to the simplest case. For more complicated networks, we carry out the Metropolis algorithm using the Mersenne Twister pseudorandom numbers.

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PP0

Pricing High-Dimensional American Options Via Gpu-Based Simulation with Gpulib.

Despite growing demand for high-dimensional derivatives pricing, efficient computation remains elusive. We address this problem by harnessing the processing power of modern graphics cards (GPUs). Tech-X Corporation has developed the GPULib library that allows users to take advantage of GPUs from high-level languages such as MATLAB without detailed hardware knowledge. We demonstrate the advantages of this library for financial computing by compar-

ing GPU- and CPU-based implementations of a stochastic mesh algorithm and other models.

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Diffusion Characterization Libraries

The Fokker-Planck Equation can provide a good estimate of the evolution of many complex dynamical systems including many financial models. However, its application across many systems is plagued by uncertainty concerning its regions of validity. Thus, it is critical when using this approach that there is a characterization of the dynamics around the action where the diffusion or frictional coefficient is calculated. This is because the Fokker-Planck equation is completely valid only in a globally stochastic region of the phase space in which adiabatic islands either do not exist or occupy negligible phase-space volume. We have recently developed a suite of library functions to test the nature of the phase space dynamics during the calculation of the diffusion coefficients in order to ascertain their validity. These libraries estimate the relevant phase decorrelation time length and determine the necessary number of time steps to calculate a valid diffusion coefficient.

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Multi-Step Simulation for Collateralized Debt Obligations

Collateralized Debt Obligations (CDOs) are an important class of asset-backed securities which offer investment opportunities with different risk-return profiles. A key component of modeling of these securities is understanding the correlation and temporal dependence of defaults in order to capture the relationship between the performance of the tranches and the underlying risk of the portfolio. Here we develop a new multi-step simulation approach which uses variance reduction techniques and quasi-Monte Carlo methods. We demonstrate this method accurately and efficiently tracks the dynamic properties of CDO cash flows.

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PP0

Modeling Chaotic Volatility

I will discuss an alternative method of modeling chaotic changes in volatility in financial models and simulation modes. In particular, I investigate how principles of semantic reasoning can be incorporated into the models and simulations.

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PP0

Using Generalized Linear Models (GLMs) to Predict Daily Returns

Computing the periodic returns is key to active portfolio management. The daily returns of stocks are not significantly correlated to their previous returns in general. But most stocks when performing better or worse than the benchmark do have 'momentum.' This increases the 'stickiness' or temporal correlation of the returns. Here we apply the Generalized Linear Models to uncover these correlations to better predict the returns.

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PP0

European Call Options: Black-Scholes Vs. Binomial Trees

We present two methods of pricing European call options. The first method follows the Black Scholes model, leading to an analytical formula for the option value. The second method is based on Binomial Trees using a discrete step in time. By choosing the parameters appropriately, the continuum limit of the Binomial Tree model coincides with the Black-Scholes model. For a finite step-size, however, the models yield different option prices. We compare numerically the results. We are investigating the relationship between this pricing model and the Binomial Trees, which are a discrete approximation of the Black-Scholes model. How similar are they? What is the percentage error of using one over the other? In what situation is it suitable to use the appropriate one? The answer to these questions is crucial for financial companies that rely on correct pricing of options. Mathematically, these problems can be solved using stochastic processes and discrete approximation theory. In this research we have developed programs for both the Black-Scholes pricing and the Binomial Trees. Currently, we are comparing the pricing results of both in order to determine rules for the usage of Trees models such that the error with comparison to the Black-Scholes model is sufficiently low. We plan to extend this research to put options as well as to American calls and puts.

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