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# **PROGRAMME** ™≏w | Daily Schedule

Overview | Daily Schedule

### **PROGRAMME OVERVIEW**

Monday	<b>Tuesday</b>	Wednesday
29 June 2015	30 June <b>2015</b>	1 July 2015
<b>08:30 – 08:50</b> Registration	08:30 – 09:00	08:30 – 09:00
<b>08:50 – 09:00</b> Opening Address	Registration	Registration
<b>09:00 – 09:45</b>	<b>09:00 – 09:45</b>	<b>09:00 – 09:45</b>
Ulrich HORST	Ronnie SIRCAR	Steven KOU
<b>09:45 – 10:15</b>	<b>09:45 – 10:15</b>	<b>09:45 – 10:15</b>
Group Photo & Tea Break	Tea Break	Tea Break
<b>10:15 – 11:00</b>	<b>10:15 – 11:00</b>	<b>10:15 – 11:00</b>
Jinniao QIU	Min DAI	Wolfgang Karl HÄRDLE
<b>11:00 – 11:45</b>	<b>11:00 – 11:45</b>	<b>11:00 – 11:45</b>
Elise GOURIER	Luis GONCALVES-PINTO	John SCHOENMAKERS
<b>11:45 – 12:10</b>	<b>11:45 – 12:10</b>	<b>11:45 – 12:10</b>
Marco MARCHIORO	Michael WOLF	Samuel DRAPEAU
12:10 – 13:30	<b>12:10 – 13:30</b>	<b>12:10 – 13:30</b>
Lunch	Lunch	Lunch
<b>13:30 – 14:15</b>	<b>13:30 – 14:15</b>	<b>13:30 – 14:15</b>
Christian BAYER	Peter FRENTRUP	Stephan STURM
<b>14:15 – 15:00</b>	14:15 – 15:00	<b>14:15 – 15:00</b>
Moritz VOSS	Randolf ALTMEYER	Chen YANG
<b>15:00 – 15:45</b> Cagin ARARAT	<b>15:00 – 15:45</b> Patrick CHAN Yuk Fung	
<b>15:45 – 16:05</b> Tea Break	<b>15:45 – 16:05</b> Tea Break	
<b>16:05 – 16:50</b>	<b>16:05 – 16:50</b>	<b>15:00 – 15:10</b>
Jussi KEPPO	Paulwin GRAEWE	Closing Address
<b>16:50 – 17:35</b> Sergey NASEKIN	<b>16:50 – 17:35</b> Yidong DONG	
<b>17:35 – 18:00</b> Chienmin CHUANG	<b>17:35 – 18:00</b> Patrick GE Pei	

Lecture theatre is equipped with desktop computer connected to LCD projector, projector screen, visualizer, overhead projector, white board, and separate connection for personal notebook or laptop. Microphone will be provided.

Monday, 29 June 2015			
TIME	ACTIVITY	VENUE	REF
08:30 - 08:50	Registration		
08:50 - 09:00	Opening Address	LT 34	
09:00 – 09:45	<b>Ulrich HORST</b> Humboldt-Universität zu Berlin, Germany <i>A Weak Law of Large Numbers for a Limit Order Book Model</i> <i>with Fully State Dependent Order Dynamics</i>	LT 34	Pg 6
09:45 – 10:15	Group Photo & Tea Break	LT 34 foyer	
10:15 – 11:00	<b>Jinniao QIU</b> Humboldt-Universität zu Berlin, Germany <i>Weak Solution for Fully Nonlinear Stochastic Hamilton-Jacobi-</i> <i>Bellman Equations and its Applications</i>	LT 34	Pg 9
11:00 – 11:45	Elise GOURIER Princeton University, USA Pricing of Equity and Variance Risks	LT 34	Pg 5
11:45 – 12:10	Marco MARCHIORO Quant Island, Singapore Risk Contribution Framework for Non-Linear Portfolios	LT 34	Pg 8
12:10 – 13:30	Lunch	LT 34 foyer	
13:30 – 14:15	<b>Christian BAYER</b> Weierstrass Institute for Applied Analysis and Stochastics, Germany <i>Volatility is Rough</i>	LT 34	Pg 1
14:15 – 15:00	Moritz VOSS Technische Universität Berlin, Germany <i>Hedging with Price Impact</i>	LT 34	Pg10
15:00 – 15:45	<b>Cagin ARARAT</b> Princeton University, USA <i>Dual Representations of Systemic Risk Measures</i>	LT 34	Pg 1
15:45 – 16:05	Tea Break	LT 34 foyer	
16:05 – 16:50	<b>Jussi KEPPO</b> National University of Singapore, Singapore <i>Bonus Caps, Deferrals and Bankers' Risk-Taking</i>	LT 34	Pg 7
16:50 – 17:35	<b>Sergey NASEKIN</b> Humboldt-Universität zu Berlin, Germany <i>Local Volatility Dynamics for Leveraged ETF Options</i>	LT 34	Pg 8
17:35 – 18:00	<b>Chienmin CHUANG</b> Risk Management Institute, Singapore Multi-asset Option Pricing using PDE approach	LT 34	Pg 2

Tuesday, 30 June 2015			
TIME	ACTIVITY	VENUE	REF
08:30 - 09:00	Registration		
09:00 - 09:45	<b>Ronnie SIRCAR</b> Princeton University, USA <i>Portfolio Choice in Uncertain Market Environments</i>	LT 34	Pg 9
09:45 – 10:15	Tea Break	LT 34 foyer	
10:15 – 11:00	Min DAI National University of Singapore, Singapore Portfolio Selection with Capital Gains Tax	LT 34	Pg 2
11:00 – 11:45	Luis GONCALVES-PINTO National University of Singapore, Singapore When Do Option Prices Predict Stock Prices?	LT 34	Pg 5
11:45 – 12:10	<b>Michael WOLF</b> University of Zurich, Switzerland <i>Nonlinear Shrinkage of the Covariance Matrix for Portfolio</i> <i>Selection: Markowitz Meets Goldilocks</i>	LT 34	Pg11
12:10 – 13:30	Lunch	LT 34 foyer	
13:30 – 14:15	<b>Peter FRENTRUP</b> Humboldt-Universität zu Berlin, Germany <i>Optimal Liquidation in a Stochastic Market Impact Model</i>	LT 34	Pg 4
14:15 – 15:00	Randolf ALTMEYER Humboldt-Universität zu Berlin, Germany Estimating Integrated and Spot Volatility in Semimartingale Models	LT 34	Pg 1
15:00 – 15:45	Patrick CHAN Yuk Fung Princeton University, USA Fracking, Renewables & Mean Field Games	LT 34	Pg 2
15:45 – 16:05	Tea Break	LT 34 foyer	
16:05 – 16:50	<b>Paulwin GRAEWE</b> Humboldt-Universität zu Berlin, Germany <i>A Non-Markovian Liquidation Problem and Backward SPDEs</i> <i>with Singular Terminal Conditions</i>	LT 34	Pg 5
16:50 – 17:35	<b>Yidong DONG</b> Princeton University, USA <i>Finite-horizon Optimal Investment under Transaction Cost</i> <i>and Stochastic Volatility</i>	LT 34	Pg 3
17:35 – 18:00	Patrick GE Pei Singapore Exchange Limited, Singapore A Hybrid Credit Risk Model for Financial Firms and its Application to CCP Counterparty Risk Management	LT 34	Pg 4

Wednesday, 1 July 2015			
TIME	ACTIVITY	VENUE	REF
08:30 – 09:00	Registration		
09:00 – 09:45	<b>Steven KOU</b> National University of Singapore, Singapore <i>Separating Skilled and Unskilled Fund Managers by Contract</i> <i>Design</i>	LT 34	Pg 7
09:45 – 10:15	Tea Break	LT 34 foyer	
10:15 – 11:00	<b>Wolfgang Karl HÄRDLE</b> Humboldt-Universität zu Berlin, Germany <i>DYFIN: Dynamic Forward Intensity curves</i>	LT 34	Pg 6
11:00 – 11:45	John SCHOENMAKERS Weierstrass Institute for Applied Analysis and Stochastics, Germany Uniform Approximation of the CIR Process via Exact Simulation at Random Times	LT 34	Pg 9
11:45 – 12:10	Samuel DRAPEAU Shanghai Jiao Tong University, China Multivariate Shortfall Risk and Monetary Risk Allocation	LT 34	Pg 3
12:10 – 13:30	Lunch	LT 34 foyer	
13:30 – 14:15	<b>Stephan STURM</b> Worcester Polytechnic Institute, USA <i>Arbitrage-Free Pricing of XVA</i>	LT 34	Pg10
14:15 – 15:00	<b>Chen YANG</b> National University of Singapore, Singapore <i>The Level of Risk-free Rate in China</i>	LT 34	Pg11
15:00 – 15:10	Closing Address	LT 34	

# All Talks

# Berlin-Princeton-Singapore Workshop on Quantitative Finance, 2015

# **Estimating Integrated and Spot Volatility in Semimartingale Models** Randolf ALTMEYER, **Humboldt**-Universität zu Berlin, Germany

I will review some basic results on estimating integrated volatility from high frequency data and present a few related projects I am working on. These include efficient (or at least rate optimal) estimation of spot volatility, estimation of the Brownian dimension, i.e. the minimal rank of the spot volatility, and also estimation in high dimensions using random matrix theory.

# Dual Representations of Systemic Risk Measures Cagin ARARAT, Princeton University, USA

A multivariate approach has recently been proposed for measuring systemic risk. In this talk, we focus on the dual representations of such multivariate risk measures and provide economic interpretations. It is shown that a systemic risk measure can be seen as a "shortfall risk measure under model uncertainty," that is, an intersection of shortfall risk measures with respect to different equivalent probability measures of the underlying model. In a network model, these probability measures can also be interpreted as the society's probability measures. As a special case, we consider a financial system with exponential aggregation mechanism, where the dual representation includes a weighted distance of the financial institutions to the society in terms of relative entropies.

# Volatility is **Rough** Christian BAYER, Weierstrass Institute for Applied Analysis and Stochastics, **Germany**

From an analysis of the time series of volatility using recent high frequency data, Gatheral, Jaisson and Rosenbaum (2014) previously showed 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 now 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.

This is a joint work with Peter Friz and Jim Gatheral.

# Fracking, Renewables & Mean Field Games Patrick CHAN Yuk Fung, Princeton University, USA

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.

# **Multi**-Asset Option Pricing Using PDE Approach Chienmin CHUANG, Risk Management Institute, Singapore

We show how to reformulate the multi-asset Black-Scholes-Merton partial differential equation/inequality (BSM PDE/PDI) and provide theorems to justify the unique solution of reformulations. In terms of discretization, we adopt the finite element method (FEM) in space and finite difference method (FDM) in time. The discrete systems of option pricing problems are presented in the form of linear system of equations (LSE) and linear complementary problems (LCP) for European and American/perpetual options respectively. The option values of European, American and perpetual types are calibrated when given various payoffs and up to three assets. Particularly, their numerical free boundaries are identified and presented in the form of (d-1)-dimensional manifold in a d-asset framework.

# **Portfolio Selection with Capital Gains Tax** Min DAI, National University of Singapore, Singapore

This talk consists of three parts. First, we develop an optimal tax-timing model that takes into account asymmetric long-term and short-term tax rates for positive capital gains and limited tax deductibility of capital losses. In contrast to the existing literature, this model can help explain why many investors not only defer short-term capital losses to long term but also defer large long-term capital gains and losses. Because the benefit of tax deductibility of capital losses increases with the short-term tax rates, effective tax rates can decrease as short-term capital gains tax rates increase. Second, we show that the value function corresponds to the minimum viscosity solution to the associated HJB equation. Third, we provide some insights on optimal strategy using asymptotic analysis.

This work is based on my recent works with Baojun Bian, Jiatu Cai, Xinfu Chen, Hong Liu, Chen Yang, and Yifei Zhong.

# **Finite**-horizon Optimal Investment under Transaction Cost and Stochastic Volatility Yidong DONG, Princeton University, USA

It is well known that in optimal investment problems with both risky and risk-free assets, the optimal strategy is governed by a key quantity called the "Merton" ratio. When the volatility is stochastic, the optimal strategy will be shifted by a certain amount. When there is proportional transaction cost associated with trading, the optimal strategy is essentially to maintain a non-trade region around the "Merton" ratio. To study the joint effect, we consider a finite horizon optimal investment problem with small proportional transaction cost and multi-scale stochastic volatility. We use asymptotic method to derive close-form approximations for the optimal strategy and compare it with some numerical results. We will also discuss some of the existing challenges in this study.

This is a joint work with Maxim Bichuch and Ronnie Sircar.

# Multivariate Shortfall Risk and Monetary Risk Allocation Samuel DRAPEAU, Shanghai Jiao Tong University, China

The financial 2007/2008 crisis revealed that too few attention was paid to a sound risk and uncertainty management in particular in its systemic dimension. In this work, we present a risk measure designed to address the global and intrinsic risk of multidimensional interconnected system such as banks or counterparty risk in a central clearing house. The goal is two fold: on the one hand, it provides the total amount of liquidity that has to be reserved for the system to overcome financial stress situations. On the other hand, it addresses the respective amount that each member has to reserve in function of their exposure to the whole system and the systemic risk they put on the system. We finally address the quantitative aspects by presenting how these high dimensional computations can be solved in an efficient manner using Fourier methods.

This is a joint work with Y. Armenti, S. Crepey and A. Papapantoleon.

# **Optimal Liquidation in a Stochastic Market Impact Model** Peter FRENTRUP, **Humboldt**-Universität zu Berlin, **Germany**

We describe a market model for trading a single risky asset, in which a large investor seeks to liquidate his position in an infinite time horizon, while maximizing expected proceeds. Trading large orders has an adverse effect on the asset's price, which is determined by the investor's current volume impact and is multiplicative in relation to the current price. The volume impact follows a mean-reverting Ornstein-Uhlenbeck process whenever no trade occurs. The martingale optimality principle suggests that the two dimensional state space of volume impact and number of held assets is separated by a free boundary into a wait- and a sell-region. We derive this free boundary using classical calculus of variations techniques in combination with local times of reflected diffusions along an elastic boundary. Verification of optimality is then reduced to showing certain analytic properties of Hermite functions, some of which remain to be fully proven.

# A Hybrid Credit Risk Model for Financial Firms and its Application to CCP Counterparty Risk Management Patrick GE Pei, Singapore Exchange Limited, Singapore

There is a regulatory push in recent years for less reliance on credit rating agencies whose credit risk assessments have long been criticized as opaque and lagging. Following this trend, central counterparties (CCPs) worldwide are developing their own credit risk models to process internal and public data. This paper investigates the driving risk factors of global financial firms on a broad basis including macroeconomic indicators, market-based DTD ("Distance-To-Default") measure and CAMEL accounting variables. Based on the multivariate regression benchmarked to observable credit spreads, an econometric model is proposed to provide a valuable reference point for financial firms in a consistent manner. This internal model provides greater insight into the risk profiles of CCP counterparties and underpins a comprehensive risk management framework. We also provide empirical tests of the model performance and discuss its implications in setting risk limits and margin add-ons.

This is a joint work with Max Wong Chan Yue (Singapore Exchange Limited, Singapore).

# When Do Option Prices Predict Stock Prices? Luis GONCALVES-PINTO, National University of Singapore, Singapore

Stocks with relatively expensive calls outperform stocks with relatively expensive puts by about 2% per month. This cross-sectional result has been associated with spillovers of informed trading from options to their underlying stocks. However, we argue that information is not the main driver of this cross-predictability. We show that the returns to this strategy are highly dependent on the state of the market. It is most profitable during periods of financial market turmoil, when there is withdrawal of liquidity supply. Its profitability is highly predictable using liquidity supply factors such as the TED spread and the level of idiosyncratic volatility. Moreover, short selling fees are not sufficient to explain this phenomenon. The characteristics of the stocks that go into this strategy's portfolio suggest that arbitrageurs could potentially bear significant amounts of undiversifiable risk when trying to explore it. This could explain why this anomaly cannot be arbitraged away in the long run, and its abnormal returns would represent compensation for the illiquidity and shorting risks borne by the small fraction of investors who do explore it.

# **Pricing of Equity and Variance Risks** Elise GOURIER, Princeton University, USA

The equity and variance risk premia represent the compensation that investors require to accept bearing the risk of fluctuations in an asset's price, respectively in its variance. They may be interpreted as measures of risk aversion and economic uncertainty associated with the drivers of asset prices. We show that variance swaps can be used in a trading strategy to take advantage of the risk premia. We introduce a framework to price variance swaps, and derive the optimal dynamic portfolio strategy in variance swaps, index, options and bonds for investors with different levels of risk aversion.

This is based on a joint work with Damir Filipovic and Loriano Mancini.

# A Non-Markovian Liquidation Problem and Backward SPDEs with Singular Terminal Conditions Paulwin GRAEWE, Humboldt-Universität zu Berlin, Germany

We establish the existence, uniqueness, and regularity of solution results for a class of backward stochastic partial differential equations with singular terminal condition. The equation describes the value function of non-Markovian stochastic optimal control problem in which the terminal state of the controlled process is prespecified. The analysis of such control problems is motivated by models of optimal portfolio liquidation.

# DYFIN: Dynamic Forward Intensity Curves Wolfgang Karl HÄRDLE, **Humboldt**-Universität zu Berlin, Germany

Reduced-form default prediction models have been limited to one-period-ahead prediction for a long time. In recent years several approaches have been made to extend these models to multi-period-ahead forecasts via duration analysis. The main difficulty of this approach is the computation of the conditional distribution of default times when employing a doubly stochastic Poisson process for modelling default events. One way of mitigating this problem is to access future values of the process' intensities via their forward counterpart. Forward intensities can be viewed as analogous to forward interest rates and are similar in their derivation. We propose the use of dynamic Nelson-Siegel forward curves to model the term structure of forward intensities with macroeconomic and firm-specific covariates. Our approach yields the full term structure of default probabilities whilst significantly reducing dimensionality compared to existing multi-period prediction models.

This is a joint work with Felix JUNG (Humboldt-Universität zu Berlin, Germany).

# A Weak Law of Large Numbers for a Limit Order Book Model with Fully State Dependent Order Dynamics Ulrich HORST, Humboldt-Universität zu Berlin, Germany

We study a one-sided limit order book (LOB) model, in which the order dynamics depend on both, the current best bid price and the current volume density function. For the joint dynamics of the best bid price and the standing buy volume density we derive a weak law of large numbers, which states that the LOB model converges to a continuous-time limit when the size of an individual order as well as the tick size tends to zero and the order arrival rate tends to infinity. In the scaling limit the standing buy volume density follows a non-linear PDE coupled with a non-linear ODE that describes the best bid price.

The talk is based on joint work with Doerte Kreher.

# Bonus Caps, Deferrals and Bankers' **Risk-Taking** Jussi KEPPO, National University of Singapore, Singapore

We model a banker's future bonuses as a series of sequential call options on the bank's profits. Bonuses provide the higher risk-taking incentive the shorter is the bonus payment interval and the higher the bonuses are relative to fixed pay. This implies that bonus caps and deferrals can reduce risk-taking. Optimal risk-taking depends on the cost of risk-taking and bonus induced risk-taking incentive under bonus restrictions. We calibrate our model to data on US banks and their CEOs' bonuses and show that increasing the bonus payment interval to two years from the standard one-year has no material effect on risk-taking. In contrast, capping the bonus to annual fixed salary significantly reduces risk-taking. Thus, our results suggest that the European Union's bonus cap helps to rein in risk-taking whereas bonus clawbacks in Dodd-Frank Act seem ineffective. Further, we find some evidence that the bonus cap is most effective in larger banks.

This is a joint work with Esa Jokivuolle (Bank of Finland and Aalto University, Finland) and Xuchuan Yuan (National University of Singapore, Singapore).

Keywords: Banking, bonuses, regulation, compensation, Dodd-Frank Act

# Separating Skilled and Unskilled Fund Managers by Contract Design Steven KOU, National University of Singapore, Singapore

Foster and Young (2010, Quarterly Journal of Economics) shows that it is very difficult to design performance fee contracts that reward skilled fund managers while screening out unskilled fund managers. In particular, none of the standard practices, such as postponing bonuses and claw back provisions, can separate skilled and unskilled managers. We show that if (1) there is a liquidation boundary, meaning that the fund investors will close the fund if the fund return is bad enough to hit the boundary, and (2) the fund manager has to use his/her own money to set up a deposit to offset the potential losses from the fund investors, then the skilled and unskilled fund managers can be separated. The deposit can be a combination of cash or an equity stake in the fund.

This is a joint work with Xuedong HE and Sang HU.

# **Risk Contribution Framework for Non-Linear Portfolios** Marco MARCHIORO, Quant Island, **Singapore**

The computation of risk contributions is a necessary complementary tool to be used in conjunction with the computation of risk measures and stress tests. Even though the theory of risk measures for a generic probability distribution has been well established, so far there seems to be no agreement in the way risk components should be computed for a portfolio with non-linear exposure to the risk drivers. In this paper we go beyond the traditional approach of using Euler's theorem to define risk contributions and we define a generic framework to compute the risk components for a generic class of risk measures known as severable risk measures. The result has a wide array of applications and matches the standard definition of risk contributions in the specific case of linear dependence from the risk-driver exposures. One of the main highlights of this framework is that the computed risk components can be made compatible with any ex-post portfolio component schema, thus creating a strong link between the worlds of risk management and that of performance measurement. Similarly to the standard case, in the case of a portfolio with a non-linear dependence from the risk-drivers we can express the risk contributions to be proportional to a newly-defined risk exposure and to the marginal risk drivers.

Keywords: Risk management, risk measures, risk attribution, risk contribution, non-linear portfolios.

# Local Volatility Dynamics for Leveraged ETF Options Sergey NASEKIN, Humboldt-Universität zu Berlin, Germany

In this research, we study the problem of local volatility surface (LVS) modelling for the leveraged ETF (LETF) options. The moneyness scaling correction of Leung and Sircar (2014) is used to allow comparison with non-leveraged ETF implied volatilities. The approximation formula reflects the role of the leverage ratio, and allows to link implied volatilities of options on leveraged and unleveraged ETFs. The LVS is modelled dynamically using the dynamic semiparametric factor model by Song et al. (2014). The corrected Dupire formula for LETF options is computed in the study.

# Weak Solution for Fully Nonlinear Stochastic Hamilton-Jacobi-Bellman Equations and its Applications Jinniao QIU, Humboldt-Universität zu Berlin, Germany

This talk is concerned with the stochastic Hamilton-Jacobi-Bellman equation with controlled leading coefficients, which is a type of fully nonlinear backward stochastic partial differential equation (BSPDE for short). In order to formulate the weak solution for such kind of BSPDEs, a class of regular random parabolic potentials are introduced in the backward stochastic framework. The existence and uniqueness of weak solution is proved, and for the partially non-Markovian case, we obtain the associated gradient estimate. The applications in finance and economics will be discussed as well.

# Uniform Approximation of the CIR Process via Exact Simulation at Random Times

# John SCHOENMAKERS, Weierstrass Institute for Applied Analysis and Stochastics, Germany

In this paper we uniformly approximate the trajectories of the Cox-Ingersoll-Ross (CIR) process. At a sequence of random times the approximate trajectories will be even exact. In between, the approximation will be uniformly close to the exact trajectory. From a conceptual point of view the proposed method gives a better quality of approximation in a path-wise sense than standard, or even exact simulation of the CIR dynamics at some deterministic time grid.

This is a joint work with G. N. Milstein.

# **Portfolio Choice in Uncertain Market Environments** Ronnie SIRCAR, Princeton University, USA

Investing in a risky asset to maximize expected utility is necessarily influenced by the nature of its uncertain volatility and uncertain growth rate (collectively, its stochastic Sharpe ratio). The classical Merton solution is the benchmark, in the case where volatility and growth rate are constant, and utility is of some specific forms. We discuss an approach to analyzing the investment problem when these constraints are not imposed, using perturbation analysis. This leads naturally to the concept of implied Sharpe ratio, analogous in many respects to implied volatility in options pricing. If there is time, we also look at the effect of transaction costs.

# **Arbitrage-Free Pricing of XVA** Stephan STURM, Worcester Polytechnic Institute, USA

We introduce a framework for computing the total valuation adjustment (XVA) of an 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's 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 a joint work with Maxim Bichuch (Johns Hopkins) and Agostino Capponi (Columbia).

# Hedging with Price Impact Moritz VOSS, Technische Universität Berlin, Germany

We consider a variant of the limit order book model by Obizhaeva and Wang (2013) which allows for both selling and buying stock. Specifically, our price impact model determines bidand ask-prices via a coupled system of controlled diffusions, allowing us to retain the possibility to specify market depth, tightness and resilience. We discuss indifference pricing and hedging of contingent claims in this model. In the limit for high resilience, we show how this can be related to the problem of tracking a target strategy in an Almgren and Chriss setup. It turns out that the optimal policy trades towards a weighted average of expected future target positions generalizing an insight from G\^arleanu and Pedersen from their homogenous Markovian optimal investment problem to a general hedging problem. This result complements a number of previous studies and sheds further light on the general structure of optimal tracking strategies in illiquid financial markets.

This is joint work with Peter Bank and Mete H. Soner.

# Nonlinear Shrinkage of the Covariance Matrix for Portfolio Selection: Markowitz Meets Goldilocks Michael WOLF, University of Zurich, Switzerland

Markowitz (1952) portfolio selection requires estimates of (i) the vector of expected returns and (ii) the covariance matrix of returns. Many successful proposals to address the first estimation problem exist by now. This paper addresses the second estimation problem. We promote a nonlinear shrinkage estimator of the covariance matrix that is more flexible than previous linear shrinkage estimators and has 'just the right number' of free parameters to estimate (that is, the Goldilocks principle). It turns out that this number is the same as the number of assets in the investment universe. Under certain high-level assumptions, we show that our nonlinear shrinkage estimator is asymptotically optimal for portfolio selection in the setting where the number of assets is of the same magnitude as the sample size. For example, this is the relevant setting for mutual fund managers who invest in a large universe of stocks. In addition to theoretical analysis, we study the real-life performance of our new estimator using backtest exercises on historical stock return data. We find that it performs better than previous proposals for portfolio selection from the literature and, in particular, that it dominates linear shrinkage.

This is a joint work with Olivier LEDOIT (University of Zurich, Switzerland).

KEY WORDS: Large-dimensional asymptotics, Markowitz portfolio selection, nonlinear shrinkage.

JEL CLASSIFICATION NOS: C13, G11.

# The Level of Risk-free Rate in China Chen YANG, National University of Singapore, Singapore

One-month SHIBOR rate, one-year fixed deposit rate and ten-year treasury yield are often employed as a proxy for the risk-free rate in China's market. However, empirical studies show that these rates are too low to reflect the actual level of risk-free rate demanded by China's market. In terms of the dual fund, an innovative structured product that is capable of capturing the characteristics of both the bond market and the equity market, we propose a point estimation of the level of China's risk-free rate under the Black-Scholes option pricing framework, as well as semi-model-free upper and lower bounds estimation based on minimal model specification. We find that the level of the risk-free rate implied from the dual fund market is uniformly higher than the commonly used risk-free rate proxies, which confirms the presence of a downward bias in the level of proxies.

This is a joint work with Min Dai, Steven Kou and Zhenfei Ye.

# **INFORMATION**

Committee | Logistics | General | Zonal Map

# Committee

# **ORGANIZING COMMITTEE**

Rene CARMONA (Princeton University, USA) Min DAI (National University of Singapore, Singapore) Ulrich HORST (Humboldt-Universität zu Berlin, Germany) Steven KOU (National University of Singapore, Singapore) Ronnie SIRCAR (Princeton University, USA) Chao ZHOU (National University of Singapore, Singapore)

# Logistics

# MEALS

Tea breaks and lunches, served buffet-style at the event venue, are catered from a Halalcertified supplier. Usually some of the food items would be suitable for vegetarians.

Dinners are not included. Nevertheless, a wide variety of food at affordable prices (from S\$2.00) is available in the non-air-conditioned canteen and air-conditioned cafe near the venue for talks. More canteens, fast food outlets and restaurants are found in other parts of the campus (refer to Zonal Map). Some are less than 10-minutes' walk away from the event venue while some are accessible by internal shuttle bus. Some stalls may open as early as 7.30am and close as late as 8.00pm. Halal and Vegetarian options are available in all canteens on campus.

# **INTERNET** ACCESS & USE OF COMPUTERS

A computing lab (S17-03-02) will be open for participants' access during the event period. It is located at level 3 of block S17 and consists of 42 desktop units that are internet-ready and installed with Windows 7, standard Microsoft Office applications, SSH, Adobe Reader, MATLAB. Limited WI-FI accounts would also be made available during event period for the convenience of those using personal notebook/laptop.

Operating hours:	8.30am – 6.00pm (Monday – Thursday)
	8.30am – 5.30pm (Friday)

Participants will have to request for account name and password to use either the computer in the computing lab, or for WI-FI access on their own notebook/laptop. Approach the IT support staff for account name and password (subject to availability).

# FAX SERVICE

Participants who wish to send faxes may do so at the general office of the Department of Mathematics (level 4, block S17). This service is chargeable at a flat rate of S\$0.50 per page.

Operating hours:	8.30am – 6.00pm (Monday – Thursday)
Operating hours:	8.30am – 5.30pm (Friday)

# **GETTING AROUND NUS**

The internal shuttle buses A, B, C, D, and UT-FoS (free-of-charge) serve the Kent Ridge campus.

Bus A1 and A2 cover substantial parts of the campus. A1 stops outside Kent Ridge MRT station, NUH and opposite S17, while A2 stops outside S17, opposite NUH and opposite Kent Ridge MRT station.

Bus A1E and A2E operates during term time on weekdays except public holidays. Bus A1E operates from 7.30am to 9.00am and stops outside Kent Ridge MRT station, and opposite S17. Bus A2E operates from 5.30pm to 7.00pm and stops outside S17, and opposite Kent Ridge MRT station.

Bus B is a loop service that serves Kent Vale and the other part of the campus. It does not stop at or anywhere near S17.

Bus C is a loop service that serves Kent Vale. It stops in front of and opposite S17.

Bus D is a loop service that serves the University Town. Bus D1 does not stop at or anywhere near S17. Bus D2 stops outside Kent Ridge MRT, opposite S17, University Town, outside S17 and opposite Kent Ridge MRT.

Bus UT-FoS is a direct service provided during term time on weekdays except public holiday at 9.40am, 9.50am, 11.40am, 11.50am, 1.40pm, 1.50pm, 3.40pm, and 3.50pm. Bus UT-FoS stops only at University Town and opposite S17.

More details on NUS internal shuttle bus can be found at: <u>http://www.nus.edu.sg/oed/services/transport/shuttle-bus-services.htm</u>

The public bus SBS95 (fare-based) stops at the same stops as A1 and A2 between S17 and Kent Ridge MRT station. It also stops near and opposite Buona Vista MRT station (which is off-campus).

# General

# **PUBLIC TRANSPORTATION**

The public transport network in Singapore consists of bus, MRT (Mass Rapid Transit), LRT (Light Rail Transit) and taxi. Buses and MRTs are the most affordable modes of public transport with standard fares ranging from S\$1.00 to S\$3.00 (depending on distance). Bus fares are charged on board by tapping a stored-value card or paying the exact fare in Singapore currency to the driver. Bus and MRT fares can be calculated using the Fare Calculator on the Public Transport website (http://www.publictransport.sg).

MRT fare is paid by tapping a Stored Value Card or a Standard Ticket at the gantry. The Standard Ticket can be used up to six times within 30 days from the date of purchase. The purchase price includes a deposit of 10 cents which will be automatically returned through an off-set against the passenger's fare on the third trip. A user also enjoys a 10-cent discount on the sixth trip. The Standard Ticket can be purchased at the General Ticketing Machine (GTM) at all MRT and LRT stations. LRTs are only available in selected residential neighbourhoods and operate similarly as MRTs.

Typically, the first bus and train starts running at 5.30am and the last service is 11.30pm daily. Special night bus services, NightRider (NR), with specific routes charge a flat rate of S\$4.50 are available from 11.30pm to 2.00am on Fridays, Saturdays and eves of Public Holidays.

Taxis can be flagged down 24 hours a day on most roads or at taxi-stands outside most major shopping centres and hotels. There is no need to bargain for prices as the taxis are all metered. The basic fare consists of a flag-down fare and a metered fare. The flag-down fare for the first kilometer or less is between \$\$3.00 and \$\$5.00, depending on the type of taxi (regular or premium). The metered fare after the first kilometer is based on the distance and waiting times during the journey. Additional charges may also be incurred depending on the time of travel and origin of the journey. A detailed rates guide is posted on the rear door of each taxi for reference.

# **GETTING TO THE AIRPORT**

The easiest way to get to the airport is by taxi. For reference, the journey from NUS with smooth traffic would take about 30 minutes and cost about S\$25.00 without surcharge. Surcharges may be incurred depending on time of travel and if the taxi was pre-booked.

To get to the airport by MRT (Mass Rapid Transit), connect to the East-West line (green line) going in the direction of Pasir Ris/Changi Airport. The Changi Airport MRT station is located under Terminals 2 and 3 which are connected to Terminal 1 by sky train. A one-way MRT fare from Kent Ridge station is about S\$2.60 (using the Standard Ticket) and takes approximately 57 minutes. More Information on MRT Network Map and fare can be found at: <u>http://www.smrt.com.sg/Journey-with-Us/Trains/Train-Map-Line-and-Station-Information</u>.

# **FOOD & SHOPPING**

Food centres and food courts serving local, Asian and sometimes international cuisine at affordable prices are commonly found in neighbourhoods and shopping malls. There would usually be at least one each of Halal and vegetarian stalls in most establishments. Operating hours of the stalls vary but most of them open by 10am and close by 9pm.

Restaurants and cafes are usually found in shopping malls and bigger neighbourhoods. Operating hours depend on the types of meals served but most would be open between 11.00am and 9.00pm.

Most shopping malls in Singapore operate from 11.00am to 10.00pm every day.

# **BANK SERVICES & FOREIGN EXCHANGE**

Participants may use major credit cards to withdraw cash using the Auto Teller Machines, which can be found in various locations on campus. Alternatively, the local banks offer regular banking services including processing foreign exchange and traveler's cheques. The nearest branches are:

DBS (Holland Village Branch) Address: 257 Holland Avenue, Singapore 278984 Tel: 1800 111 1111 Operating hours: 8.30am - 4.30pm (Monday – Friday) 8.30am - 1.00pm (Saturday) DBS/POSB (NUS Remix Branch) Address: 31 Lower Kent Ridge Road, #01-02 Yusof Ishak House, Singapore 119078 Tel: 1800 111 1111 Operating hours: 8.30 AM - 4.30 PM (Monday – Friday) 8.30 AM - 1.00 PM (Saturday) Only Personal Banking Services are available. Demand Draft and Remittance services are not available. All cash transactions must be made at Automated Teller Machines. DBS (Clementi Branch) Address: Blk 450 Clementi Avenue 3 #01-293/295, Singapore 120450 Tel: 1800 111 1111 Operating hours: 8.30am - 4.30pm (Monday – Friday) 8.30am - 1.00pm (Saturday) UOB (Holland Village Branch) Address: 211 Holland Avenue, #01-12 Holland Road Shopping Centre, Singapore 278967 1800 222 2121 Tel: Operating hours: 9.30am - 4.00pm (Monday – Friday) 9.00am - 12.30pm (Saturday)

# **POST BOX & POSTAGE STAMPS**

Postage stamps can be purchased at the NUS Coop store below Lecture Theatre 27. Other goods and services available at the co-op include books, stationery, sundries and photocopying.

Operating hours (co-op): 9.00am – 6.00pm (Monday – Friday)

A post box is stationed near the bus stop in front of Block S17.

### **USEFUL PHONE NUMBERS**

Taxi (for current and	advanced bool	king):
<u>Company</u>	Telephone	Colour of vehicle
CityCab	65521111	Yellow
Comfort Taxi	65521111	Blue
Premier Taxis	63636888	Silver
Prime Taxis	67780808	Copper (regular service); Blue (limousine service)
SMRT Taxis	65558888	White
Trans Cab	65553333	Red
Yellow Top Taxis	62935545	Yellow top with black body

Local Emergency Services for Credit Cards:

American Express	1800-299-1997
Diner's Club Singapore	64160800(during office hours); 64160900 (after office hours)
MasterCard	800-1100-113
Visa	800-4481-250
JCB	001-800-3865-5486

# Others:

Tourist Information (Singapore Tourism Board)	1800-7362000
24-hour Flight Enquiry (Changi Airport)	1800-5424422
Buona Vista Neighbourhood Police Post	1800-7779999
Police Emergency	999
Non-emergency Ambulance	1777
Fire Engine/Ambulance	995

# Zonal Map



Map powered by Streetdirectory.com

- $\bigstar$
- Workshop venue (S17)

Canteen/Food Court

- Bus-stop
- **•••**

- Restaurant
- Coffee joints (Platypus at Science Canteen; Spinelli at Science canteen; The Coffee Bean at NUH; Starbucks at School of Medicine)
- \$
- Auto Teller Machine