Quantitative Finance Research Newsletter
Oxford-Man Institute
OMIReNew



The Oxford-Man Institute of Quantitative Finance is a world-leading centre for interdisciplinary research in financial markets. This newsletter is an eclectic summary that covers the most recent research of relevance to quantitative finance, from a wide range of disciplines in academia and industry.

***This issue**: Quantitative Finance & Economics, Machine Learning for Finance, Graph-based Learning, Derivatives & Volatility, Risk Management, NLP & Fundamental Data, Cryptocurrencies & Blockchain.*

Highlights

This month's edition contains several thought provoking works across a wide range of topics for our inter-disciplinary field. Noteworthy works, include a work from Imperial College studying quantum effects in an expanded Black-Scholes model. Two papers - one from Waterloo and another from Bloomberg focusing on enhancing Value at Risk as a measure of risk. Work on Tail-GAN from Oxford is intriguing as it focuses on simulation of realistic multi-asset scenarios, which with a more accurate estimation of tail risks. Kansas Fed's work studying FOMC announcements to quantify the term structure of uncertainty is also noteworthy. A new section covering cryptocurrencies and blockchain has also been added. Finally, it would be remiss not to highlight the last publication of one of the most remarkable Quants of our time, Prof. Peter Carr, who suddenly passed away last month.

Quantitative Finance & Economics

Power Laws in Market Microstructure

U. Cetin, and H. Waelbroeck
London School of Economics

The work develops an equilibrium model for market impact of trades when investors with private signals execute via a trading desk. Fat tails in the signal distribution lead to a power law for price impact, while the impact is logarithmic for lighter tails. Moreover, the tail distribution of the equilibrium trade volume obeys a power law. The spread decreases with the degree of noise trading and increases with the number of insiders. In case of a monopolistic insider, the last slice traded against the limit order book is priced at the fundamental value of the asset reminiscent of Kyle (1985). However, competition among insiders leads to aggressive trading, hence vanishing profit in the limit. The model also predicts that the order book flattens as the amount of noise trading increases converging to a model with proportional transactions costs with non-vanishing spread.

Trade wars and asset prices

G. Carlomagno, and E. Albagli
Central Bank of Chile

The work formulates the effects of the trade war between the US and China since 2018 on international asset markets, including bonds, stocks, and exchange rates for a sample of 36 developed and emerging economies. The main methodology relies on event studies, based on a daily indicator of trade-war news. Authors find that the typical negative news significantly and persistently compresses 10-y yields in the US and other developed economies, leading to cumulative effects close to 67 bp and 32 bp over the sample period, respectively. These episodes also significantly reduce stock markets in the US and other developed economies, with cumulative effects close to 23 and 14% for developed and emerging economies, respectively. For emerging

countries, authors find significant currency depreciations against the USD. These results are confirmed with an alternative identification based on time-varying volatility. Given the relatively larger impacts on long-term yields, as well as the differential effects across developed and emerging markets, leading to conclude that the dominant channel behind the effects are increases in global risk aversion, as opposed to worsening perspectives about global growth prospects.

Trading with the Crowd

E. Neuman, and M. Vob
Imperial College London, & UCLA

The work formulates and solves a multi-player stochastic differential game between financial agents who seek to cost-efficiently liquidate their position in a risky asset in the presence of jointly aggregated transient price impact, along with taking into account a common general price predicting signal. The unique Nash-equilibrium strategies reveal how each agent's liquidation policy adjusts the predictive trading signal to the aggregated transient price impact induced by all other agents. This unfolds a quantitative relation between trading signals and the order flow in crowded markets. The work also formulate and solve the corresponding mean field game in the limit of infinitely many agents. Authors prove that the equilibrium trading speed and the value function of an agent in the finite N-player game converges to the corresponding trading speed and value function in the mean field game at rate O(N^2). In addition, the work proves that the mean field optimal strategy provides an approximate Nash-equilibrium for the finite-player game.

Phases of MANES: Multi-Asset Non-Equilibrium Skew Model of a Strongly Non-Linear Market with Phase Transitions

I. Halperin
Fidelity Investments

This paper presents an analytically tractable and practically-oriented model of non-linear dynamics of a multi-asset market in the limit of a large number of assets. The asset price dynamics are driven by money flows into the market from external investors, and their price impact. This leads to a model of a market as an ensemble of interacting non-linear oscillators with the Langevin dynamics. In a homogeneous portfolio approximation, the mean field treatment of the resulting Langevin dynamics produces the McKean-Vlasov equation as a dynamic equation for market returns. Due to the strong non-linearity of the McKean-Vlasov equation, the resulting dynamics give rise to ergodicity breaking and first- or second-order phase transitions under variations of model parameters. Using a tractable potential of the Non-Equilibrium Skew (NES) model previously suggested by the author for a single-stock case, the new Multi-Asset NES (MANES) model enables an analytically tractable framework for a multi-asset market. The equilibrium expected market log-return is obtained as a self-consistent mean field of the McKean-Vlasov equation, and derived in closed form in terms of parameters that are inferred from market prices of SP 500 index options. The model is able to accurately fit the market data for either a benign or distressed market environments, while using only a single volatility parameter.

Should the ECB Adjust Its Strategy in the Face of a Lower R*?

P. Andrade, J. Goli, H. Bihan, and J. Matheron
MIT, Banque de France, & FRB of Boston

The work addresses the question in this paper's title using an estimated New Keynesian DSGE model of the euro area with trend inflation, imperfect indexation, and a lower bound on the nominal interest rate. In this setup, a decrease in the steady-state real interest rate, r*, increases the probability of hitting the lower bound constraint, which entails significant welfare costs and warrants an adjustment of the monetary policy strategy. Under an unchanged monetary policy rule, an increase in the inflation target of eight-tenths the size of the drop in the real natural rate of interest is warranted. Absent an increase in the inflation target, and assuming the effective lower bound prevents the European Central Bank from implementing more aggressive negative interest rate policies, adjusting the monetary strategy requires considering alternative instruments or policy rules, such as a commitment to make up for recent, below-target inflation realizations.

Machine Learning for Finance

Universal Approximation of Credit Portfolio Losses Using Restricted Boltzmann Machine.

G. Genovese, A. Nikeghbali, N. Serra, and G. Visentin
University of Zurich

The work introduces a new portfolio credit risk model based on Restricted Boltzmann Machines (RBMs), which are stochastic neural networks capable of universal approximation of loss distributions. Authors test the model on an empirical dataset of default probabilities of 30 investment grade US companies and show that it outperforms commonly used parametric factor copula models – such as the Gaussian or the t factor copula models – across several credit risk management tasks. In particular, the model leads to better out-of-sample fits for the empirical loss distribution and more accurate risk measure estimations. The work introduces an importance

sampling procedure which allows risk measures to be estimated at high confidence levels in a computationally efficient way and which is a substantial improvement over the Monte Carlo techniques currently available for copula models. Furthermore, the statistical factors extracted by the model admit an interpretation in terms of the underlying portfolio sector structure and provide practitioners with quantitative tools for the management of concentration risk. Finally, the work shows how to use the model for stress testing by estimating stressed risk measures (e.g. stressed VaR) for their empirical portfolio under various macroeconomic stress test scenarios, such as those specified by the FRB's Dodd-Frank Act stress test.

Stripping the Discount Curve - a Robust Machine Learning Approach

D. Filipović, M. Pelger, and Y. Ye
Swiss Finance Institute & Stanford University

The work introduces a robust, flexible and easy-to-implement method for estimating the yield curve from Treasury securities. This method is non-parametric and optimally learns basis functions in reproducing Hilbert spaces with an economically motivated smoothness reward. The authors provide a closed-form solution of their machine learning estimator as a simple kernel ridge regression, which is straightforward and fast to implement. The work shows in an extensive empirical study on U.S. Treasury securities, that their method strongly dominates all parametric and non-parametric benchmarks. Their method achieves substantially smaller out-of-sample yield and pricing errors, while being robust to outliers and data selection choices. They attribute the superior performance to the optimal trade-off between flexibility and smoothness, which positions their method as the new standard for yield curve estimation.

Deep Regression Ensembles

A. Didisheim, B. Kelly, and S. Malamud
CEPR, Swiss Finance Institute, Yale University, & NBER

The work introduces a methodology for designing and training deep neural networks (DNN) that the authors call "Deep Regression Ensembles" (DRE). It bridges the gap between DNN and two-layer neural networks trained with random feature regression. Each layer of DRE has two components, randomly drawn input weights and output weights trained myopically (as if the final output layer) using linear ridge regression. Within a layer, each neuron uses a different subset of inputs and a different ridge penalty, constituting an ensemble of random feature ridge regressions. The experiments show that a single DRE architecture is at par with or exceeds state-of-the-art DNN in many data sets. Yet, because DRE neural weights are either known in closed-form or randomly drawn, its computational cost is orders of magnitude smaller than DNN.

Machine Forecast Disagreement and Equity Returns

T. Bali, R. Chang, and B. Kelly
Georgetown & Yale University

The work proposes a belief-generating model from which the work builds a statistical measure of investor disagreement. The authors simulate differences in beliefs across investors by endowing them with different machine learning models for forecasting returns from the same set of inputs. They measure disagreement as the standard deviation of expected return forecasts across investors, which captures divergence of opinion emerging from differences in the way investors perceive and use available information. They document a significantly negative cross-sectional relation between investor disagreement and future stock returns. A long-short portfolio of stocks sorted by disagreement provides a six-factor Fama-French (2018) alpha of 0.68% (0.93%) per month for the value-weighted (equal-weighted) portfolio. And finally, they present evidence that this return predictability is driven by mispricing induced by information frictions, short-selling costs, and limits-to-arbitrage.

NumHTML: Numeric-Oriented Hierarchical Transformer Model for Multi-task Financial Forecasting

L. Yang, J. Li, R. Dong, Y. Zhang, and B. Smyth
University of Warwick & UCD

Financial forecasting has been an important and active area of machine learning research because of the challenges it presents and the potential rewards that even minor improvements in prediction accuracy or forecasting may entail. Traditionally, financial forecasting has heavily relied on quantitative indicators and metrics derived from structured financial statements. Earnings conference call data, including text and audio, is an important source of unstructured data that has been used for various prediction tasks using deep earning and related approaches. However, current deep learning-based methods are limited in the way that they deal with numeric data; numbers are typically treated as plaintext tokens without taking advantage of their underlying numeric structure. This paper describes a numeric-oriented hierarchical transformer model (NumHTML) to predict stock returns, and financial risk using multimodal aligned earnings calls data by taking advantage of the different categories of numbers (monetary, temporal, percentages etc.) and their magnitude. We present the results of a comprehensive evaluation of NumHTML against several state-of-the-art baselines using a real-

world publicly available dataset. The results indicate that NumHTML significantly outperforms the current state-of-the-art across a variety of evaluation metrics and that it has the potential to offer significant financial gains in a practical trading context.

FinRL-Meta: A Universe of Near-Real Market Environments for Data-Driven Deep Reinforcement Learning in Quantitative Finance

X. Liu

Columbia University

Deep reinforcement learning (DRL) has shown huge potentials in building financial market simulators recently. However, due to the highly complex and dynamic nature of real-world markets, raw historical financial data often involve large noise and may not reflect the future of markets, degrading the fidelity of DRL-based market simulators. Moreover, the accuracy of DRL-based market simulators heavily relies on numerous and diverse DRL agents, which increases demand for a universe of market environments and imposes a challenge on simulation speed. This work presents a FinRL-Meta framework that builds a universe of market environments for data-driven financial reinforcement learning. First, FinRL-Meta separates financial data processing from the design pipeline of DRL-based strategy and provides open-source data engineering tools for financial big data. Second, FinRL-Meta provides hundreds of market environments for various trading tasks. Third, FinRL-Meta enables multiprocessing simulation and training by exploiting thousands of GPU cores.

Tail-GAN: Nonparametric Scenario Generation for Tail Risk Estimatio

R. Cont, M. Cucuringu, R. Xu, and C. Zhang

University of Oxford, & University of Southern California

The estimation of loss distributions for dynamic portfolios requires the simulation of scenarios representing realistic joint dynamics of their components, with particular importance devoted to the simulation of tail risk scenarios. Commonly used parametric models have been successful in applications involving a small number of assets, but may not be scalable to large or heterogeneous portfolios involving multiple asset classes. Authors propose a novel data-driven approach for the simulation of realistic multi-asset scenarios with a particular focus on the accurate estimation of tail risk for a given class of static and dynamic portfolios selected by the user. By exploiting the joint elicitability property of Value-at-Risk (VaR) and Expected Shortfall (ES), they design a Generative Adversarial Network (GAN) architecture capable of learning to simulate price scenarios that preserve tail risk features for these benchmark trading strategies, leading to consistent estimators for their Value-at-Risk and Expected Shortfall. They demonstrate the accuracy and scalability of their method via extensive simulation experiments using synthetic and market data. Their results show that, in contrast to other data-driven scenario generators, their proposed scenario simulation method correctly captures tail risk for both static and dynamic portfolios.

Graph-based Learning

Dynamic clearing and contagion in financial networks

T. Banerjee, A. Bernstein, and Z. Feinstein

Washington University & UCSB

This work introduces a generalized extension of the Eisenberg-Noe model of financial contagion to allow for time dynamics of the interbank liabilities, including a dynamic examination of default risk. This framework separates the cash account and long-term capital account to more accurately model the health of a financial institution. In doing so, such a system allows us to distinguish between defaults resulting from either insolvency or illiquidity, and to analyze the resulting effects on the rest of the network.

Financial time series forecasting with multi-modality graph neural network

D. Cheng, F. Yang, S. Xiang, and J. Liu

University of Technology Sydney, and Tongji University

Financial time series analysis plays a central role in hedging market risks and optimizing investment decisions. This is a challenging task as the problems are always accompanied by multi-modality streams and lead-lag effects. For example, the price movements of stock are reflections of complicated market states in different diffusion speeds, including historical price series, media news, associated events, etc. Furthermore, the financial industry requires forecasting models to be interpretable and compliant. Therefore, authors propose a multi-modality graph neural network (MAGNN) to learn from these multimodal inputs for financial time series prediction. The heterogeneous graph network is constructed by the sources as nodes and relations in their financial knowledge graph as edges. To ensure the model interpretability, the work leverages a two-phase attention mechanism for joint optimization, allowing end-users to investigate the importance of inner-modality and inter-modality sources. Extensive experiments on real-world datasets demonstrate the superior performance of MAGNN in financial market prediction. Their method provides investors with a profitable as well as interpretable option and enables them to make informed

investment decisions.

Bayesian Learning of Graph Substructures

W. Bloom, and M. Ioro
National University of Singapore

Graphical models provide a powerful methodology for learning the conditional independence structure in multivariate data. Inference is often focused on estimating individual edges in the latent graph. Nonetheless, there is increasing interest in inferring more complex structures, such as communities, for multiple reasons, including more effective information retrieval and better interpretability. Stochastic blockmodels offer a powerful tool to detect such structure in a network. The work thus propose to exploit advances in random graph theory and embed them within the graphical models framework. A consequence of this approach is the propagation of the uncertainty in graph estimation to large-scale structure learning. They consider Bayesian nonparametric stochastic blockmodels as priors on the graph. They extend such models to consider clique-based blocks and to multiple graph settings introducing a novel prior process based on a dependent Dirichlet process. Moreover, they devise a tailored computation strategy of Bayes factors for block structure based on the Savage-Dickey ratio to test for presence of larger structure in a graph. They demonstrate their approach in simulations as well as on real data applications in finance and transcriptomics.

A Bayesian Graphical Approach for Large-Scale Portfolio Management with Fewer Historical Data

S. Oya
Keio University

Managing a large-scale portfolio with many assets is one of the most challenging tasks in the field of finance. It is partly because estimation of either covariance or precision matrix of asset returns tends to be unstable or even infeasible when the number of assets p exceeds the number of observations n. For this reason, most of the previous studies on portfolio management have focused on the case of $p < n$. To deal with the case of $p > n$, the work proposes to use a new Bayesian framework based on adaptive graphical LASSO for estimating the precision matrix of asset returns in a large-scale portfolio. Unlike the previous studies on graphical LASSO in the literature, their approach utilizes a Bayesian estimation method for the precision matrix proposed by Oya and Nakatsuma (2022) so that the positive definiteness of the precision matrix should be always guaranteed. As an empirical application, the work constructs the global minimum variance portfolio of $p = 100$ for various values of n with the proposed approach as well as the non-Bayesian graphical LASSO approach, and compare their out-of-sample performance with the equal weight portfolio as the benchmark. In this comparison, the proposed approach produces more stable results than the non-Bayesian approach in terms of Sharpe ratio, portfolio composition and turnover. Furthermore, the proposed approach succeeds in estimating the precision matrix even if n is much smaller than p and the non-Bayesian approach fails to do so.

Graphi Similarity Learning For Change-Point Detection In Dynamic Networks

D. Sulem, H. Kenlay, M. Cucuringu, and X. Dong
University of Oxford

Dynamic networks are ubiquitous for modelling sequential graph-structured data, e.g., brain connectome, population flows and messages exchanges. This work considers dynamic networks that are temporal sequences of graph snapshots, and aim at detecting abrupt changes in their structure. This task is often termed network change-point detection and has numerous applications, such as fraud detection or physical motion monitoring. Leveraging a graph neural network model, the authors design a method to perform online network change-point detection that can adapt to the specific network domain and localise changes with no delay. The main novelty of our method is to use a siamese graph neural network architecture for learning a data-driven graph similarity function, which allows to effectively compare the current graph and its recent history. Importantly, our method does not require prior knowledge on the network generative distribution and is agnostic to the type of change-points; moreover, it can be applied to a large variety of networks, that include for instance edge weights and node attributes. They show on synthetic and real data that our method enjoys a number of benefits: it is able to learn an adequate graph similarity function for performing online network change-point detection in diverse types of change-point settings, and requires a shorter data history to detect changes than most existing state-of-the-art baselines.

Derivatives & Volatility

FX option volume

R. Czech, P. Corte, S. Huang, and T. Wang
Bank of England

The work studies the information content of foreign exchange (FX) option volume using a unique dataset on over-the-counter FX options with disclosed counterparty identities and contract characteristics. Their study shows that FX option volume can predict future exchange rate returns, especially when the demand for the US dollar is

high. In support of information-based arguments, authors also document that the exchange rate predictability is stronger around macro-announcement days or when using options with higher embedded leverage. Finally, they show that hedge funds and real money investors have superior skills in predicting future exchange rates compared to other investor types.

Optimal Damping with Hierarchical Adaptive Quadrature for Efficient Fourier Pricing of Multi-Asset Options in L´evy Models

C. Bayer, C. Hammouda, A. Papapantoleon, M. Samet, and R. Tempone

TU Delft & Aachen University

Efficient pricing of multi-asset options is a challenging problem in quantitative finance. When the Fourier transform of the density function is available, Fourier-based pricing methods become very competitive compared to alternative techniques because the integrand in the frequency space has often higher regularity than in the physical space. However, when designing a numerical quadrature method for most of these Fourier pricing approaches, two key aspects affecting the numerical complexity should be carefully considered: (i) the choice of the damping parameters that ensure integrability and control the regularity class of the integrand and (ii) the effective treatment of the high dimensionality of the integration problem. To address these challenges, based on the extension of the one-dimensional Fourier valuation formula to the multivariate case, authors propose an efficient numerical method for pricing European multi-asset options based on two complementary ideas. First, they smooth the Fourier integrand via an optimized choice of damping parameters based on a proposed heuristic optimization rule. Second, they use the adaptive sparse grid quadrature based on sparsification and dimension-adaptivity techniques to accelerate the convergence of the numerical quadrature in high dimensions. Through an extensive numerical study on the basket and rainbow options under the multivariate geometric Brownian motion and some multivariate L´evy models, they demonstrate the advantages of adaptivity and their damping parameter rule on the numerical complexity of the quadrature methods. Moreover, they reveal that their approach achieves substantial computational gains compared to the Monte Carlo method for different dimensions and parameter constellations.

Predicting Recessions Using VIX-Yield-Curve Cycles

A. Hansen

Federal Reserve Bank of Richmond

The VIX index and the spread between long- and short-term Treasury bond yields co-move in counterclockwise cycles that align with the business cycle. Based on this empirical fact, I predict U.S. recessions using an indicator of the economy's location on the VIX-yield-curve cycle. The proposed indicator significantly outperforms the yield-curve spread in predicting U.S. recessions from 1990–2021 both in- and outof-sample using both static and dynamic probit models. VIX-yield-curve cycles also contain predictive power above and beyond other leading economic indicators.

A highly efficient tensor network algorithm for multi-asset Fourier options pricing

M. Kastroyano, and N. Pancotti3

Amazon

Risk assessment and in particular derivatives pricing is one of the core areas in computational finance and accounts for a sizeable fraction of the global computing resources of the financial industry. They outline a quantum-inspired algorithm for multi-asset options pricing. The algorithm is based on tensor networks, which have allowed for major conceptual and numerical breakthroughs in quantum many body physics and quantum computation. In the proof-of-concept example explored, the tensor network approach yields several orders of magnitude speedup over vanilla Monte Carlo simulations. They take this as good evidence that the use of tensor network methods holds great promise for alleviating the computation burden of risk evaluation in the financial and other industries, thus potentially lowering the carbon footprint these simulations incur today.

A mean-field game of market-making against strategic traders

B. Baldacci, P. Bergault, and D. Possamaï

ETH Zurich and Ecole Polytechnique

The work designs a market-making model à la Avellaneda and Stoikov in which the market-takers act strategically, in the sense that they design their trading strategy based on an exogenous trading signal. The market-maker chooses her quotes based on the average market-takers' behaviour, modelled through a mean-field interaction. They derive, up to the resolution of a coupled HJB–Fokker–Planck system, the optimal controls of the market-maker and the representative market-taker. This approach is flexible enough to incorporate different behaviours for the market-takers and takes into account the impact of their strategies on the price process.

Quantum effects in an expanded Black–Scholes model

A. Bhatnagar, and D. Vvedensky
Imperial College London

The limitations of the classical Black–Scholes model are examined by comparing calculated and actual historical prices of European call options on stocks from several sectors of the SP 500. Persistent differences between the two prices point to an expanded model proposed by Segal and Segal (1998) in which information not simultaneously observable or actionable with public information can be represented by an additional pseudo-Wiener process. A real linear combination of the original and added processes leads to a commutation relation analogous to that between a boson field and its canonical momentum in quantum field theory. The resulting pricing formula for a European call option replaces the classical volatility with the norm of a complex quantity, whose imaginary part is shown to compensate for the disparity between prices obtained from the classical Black–Scholes model and actual prices of the test call options. This provides market evidence for the influence of a non-classical process on the price of a security based on non-commuting operators.

Rough volatility: fact or artefact?

R. Cont, and P. Das
University of Oxford

The work investigates the statistical evidence for the use of 'rough' fractional processes with Hurst exponent $H < 0.5$ for the modeling of volatility of financial assets, using a model-free approach. They introduce a non-parametric method for estimating the roughness of a function based on discrete sample, using the concept of normalized p-th variation along a sequence of partitions. They investigate the finite sample performance of their estimator for measuring the roughness of sample paths of stochastic processes using detailed numerical experiments based on sample paths of fractional Brownian motion and other fractional processes. They then apply this method to estimate the roughness of realized volatility signals based on high-frequency observations. Detailed numerical experiments based on stochastic volatility models show that, even when the instantaneous volatility has diffusive dynamics with the same roughness as Brownian motion, the realized volatility exhibits rough behaviour corresponding to a Hurst exponent significantly smaller than 0.5. Comparison of roughness estimates for realized and instantaneous volatility in fractional volatility models with different values of Hurst exponent shows that, irrespective of the roughness of the spot volatility process, realized volatility always exhibits 'rough' behaviour with an apparent Hurst index $H < 0.5$. These results suggest that the origin of the roughness observed in realized volatility time-series lies in the microstructure noise rather than the volatility process itself.

Risk Management

Rating transitions forecasting: a filtering approach

A. Cousin, J. Lelong, and T. Picard
Univ. Grenoble Alpes, & Universite de Strasbourg

Analyzing the effect of business cycle on rating transitions has been a subject of great interest these last fifteen years, particularly due to the increasing pressure coming from regulators for stress testing. In this paper, authors consider that the dynamics of rating migrations is governed by an unobserved latent factor. Under a point process filtering framework, they explain how the current state of the hidden factor can be efficiently inferred from observations of rating histories. They then adapt the classical Baum-Welch algorithm to their setting and show how to estimate the latent factor parameters. Once calibrated, they reveal and detect economic changes affecting the dynamics of rating migration, in real-time. To this end they adapt a filtering formula which can then be used for predicting future transition probabilities according to economic regimes without using any external covariates. They propose two filtering frameworks: a discrete and a continuous version. They demonstrate and compare the efficiency of both approaches on fictive data and on a corporate credit rating database. The methods could also be applied to retail credit loans.

A reverse Expected Shortfall optimization formula

Y. Guan, Z. Jiao, and R. Wang
University of Waterloo, and DePaul University

The celebrated Expected Shortfall (ES) optimization formula implies that ES at a fixed probability level is the minimum of a linear real function plus a scaled mean excess function. They establish a reverse ES optimization formula, which says that a mean excess function at any fixed threshold is the maximum of an ES curve minus a linear function. Despite being a simple result, this formula reveals elegant symmetries between the mean excess function and the ES curve, as well as their optimizers. The reverse ES optimization formula is closely related to the Fenchel-Legendre transforms, and their formulas are generalized from ES to optimized certainty equivalents, a popular class of convex risk measures. They analyze worst-case values of the mean

excess function under two popular settings of model uncertainty to illustrate the usefulness of the reverse ES optimization formula, and this is further demonstrated with an application using insurance datasets.

Bayesian Backtesting for Counterparty Risk Models

M. Arnsdorf, and M. Zelvyte
University of Waterloo, and DePaul University

In this article they introduce a new framework for counterparty risk model backtesting based on Bayesian methods. This provides a conceptually sound approach for analyzing model performance which is also straightforward to implement. They show that their methodology provides important advantages over a typical, classical, backtesting set-up. In particular, they find that the Bayesian approach outperforms the classical one in identifying whether a model is correctly specified which is the principal aim of any backtesting framework. The power of the methodology is due to its ability to test individual model parameters and hence identify which aspects of a model are misspecified as well as the degree of misspecification. This greatly facilitates the impact assessment of model issues as well as their remediation.

A New Stochastic Inflation Model for Inflation Derivatives

M. Xu
AIG

Inflation derivatives have been widely used by various institutions to transfer or hedge inflation risks. They have experienced substantial growth since early 2000s and a liquid market has been developing in both Europe and U.S. In order to price inflation derivatives, calculate their risks or perform scenario analysis, a stochastic inflation model is required. Existing stochastic inflation models in the literature have some well-known shortcomings, for instance, modeling unnecessary non-market observables, inflexibility in inflation volatility structure, complexity in model calibration and derivative pricing, etc. In this paper they propose a new stochastic forward inflation index model by combining individual existing models' strengths while avoiding their weaknesses, especially in the post LIBOR era. With the new inflation model efficient and accurate closed-form pricing formulas are derived for most inflation derivatives, which are then used to calibrate the inflation index term structure as well as the volatility structure. With a stochastic inflation model calibrated, scenarios of a variety of market observables can be simulated efficiently for various applications in a Monte Carlo simulation, in either the risk-neutral or real-world measure.

Speeding up VaR with VDR

M. Bondioli, S. Maydan, H. Stein, and Y. Zhang
Bloomberg

Calculating risk measures can be extremely time consuming for large portfolios. Monte Carlo and historical value at risk and expected shortfall calculations can require repricing 1,000s of positions 1,000s of times. This makes risk calculations extremely challenging when the pricing functions themselves are slow. To make the calculations tractable, shortcuts (such as matrix pricing or reducing the number of scenarios) are often taken. But these approaches often reduce accuracy as well. Here they present what they call the virtual dimensional reduction (VDR) method. By leveraging the geometry (shape) of the pricing function domain, they can accurately perform VaR calculations with as little as 50-100 price calculations, thus yielding a speed-up of 10-20x compared to full valuation with 1,000 scenarios.

Long Term Risk: A Time Change Approach

P. Carr, and U. Cherubini
New York University & University of Bologna

The work studies an asset pricing model in which a Stochastic Discount Factor (SDF) and a growth process have independent increments and are affected by a common stochastic clock. The stochastic clock is a strictly increasing process that may include a persistent component, that they call comonotonic, and represents sources of long run uncertainty, such as those induced by climate change issues. They find that long term log-returns are lower the higher the variance of the clock, and the more relevant its comonotonic component. The comonotonic component in the clock induces a separation of the SDF dynamics between persistent and transitory shocks similar to that assumed in the long term risk literature, with the difference that the system is non Markovian. They also provide an axiomatic definition of the compounding operation leading to an associative algebraic structure, with generator represented by the Laplace transform of the stochastic clock increments. The same generator characterizes the Archimedean copula function linking the SDF and the growth process.

On a CCP Model Linking Market Gaps to Defaults

A. Dickinson
Bank of America

The work presents a dynamic model of a Central Counterparty (CCP) and use it to quantify the associated credit risks. First, they apply the model to obtain a closed-form approximation to the Credit Valuation Adjustment (CVA) arising due to membership of a CCP; then, they apply the model to economic capital and derive a semi-

analytic approximation to the full distribution of losses upto a fixed time horizon. Through a novel mechanism linking margin calls and default times, they investigate the potential wrong-way risk arising due to an extremal margin call triggering the default of a CCP member that holds insufficient capital. They conclude that excessive leverage may increase credit risk to such an extent that a single CCP member clearing an outsized, speculative position may contribute more risk than all the other members combined.

Measuring non-exchangeable tail dependence using tail copulas

T. Koike, S. Kato, and M. Hofert
University of Waterloo, and ISM Tokyo

Quantifying tail dependence is an important issue in insurance and risk management. The prevalent tail dependence coefficient (TDC), however, is known to underestimate the degree of tail dependence and it does not capture non-exchangeable tail dependence since it evaluates the limiting tail probability only along the main diagonal. To overcome these issues, two novel tail dependence measures called the maximal tail concordance measure (MTCM) and the average tail concordance measure (ATCM) are proposed. Both measures are constructed based on tail copulas and possess clear probabilistic interpretations in that the MTCM evaluates the largest limiting probability among all comparable rectangles in the tail, and the ATCM is a normalized average of these limiting probabilities. In contrast to the TDC, the proposed measures can capture non-exchangeable tail dependence. Moreover, they often admit analytical forms and satisfy axiomatic properties naturally required to quantify tail dependence. A real data analysis reveals striking tail dependence and tail non-exchangeability of the return series of stock indices, particularly in periods of financial distress.

NLP & Fundamental Data

What Do They Mean? An Application of Latent Semantic Analysis to the Bank of England MPC Minutes

P. Dixon
Independent

This paper applies data science techniques, specifically natural language processing algorithms, to a corpus comprised of the Bank of England's MPC minutes. Whilst acknowledging that there is a considerable amount of fuzziness surrounding the use of such techniques, there is some evidence to suggest that the BoE's communications have been heavily based around the inflation-targeting regime which forms the core of its operational mandate. This is despite the fact that a significant number of competing factors have impacted on the operation of the BoE's monetary policy in recent years.

The Term Structure of Monetary Policy Uncertainty

B. Bundick, A. Smith, and T. Herriford
Federal Reserve of Kansas City

This paper studies the transmission of Federal Reserve communication to financial markets and the economy using new measures of the term structure of policy rate uncertainty. Movements in the term structure of interest rate uncertainty around FOMC announcements cannot be summarized by a single measure but, instead, are two dimensional. The work characterises these two dimensions as the level and slope factors of the term structure of interest rate uncertainty. These two monetary policy uncertainty factors significantly help to explain changes in Treasury yields and forward real interest rates around FOMC announcements, even after accounting for changes in the expected path of policy rates. Moreover, the work demonstrates that focusing in just a single dimension of monetary policy uncertainty provides an inaccurate description of how policy uncertainty shapes the transmission of FOMC announcements. Finally, their policy uncertainty factors provide stronger first-stage instruments in a proxy SVAR setting, which implies more expansionary macroeconomic effects of forward guidance than those estimated only using the expected path of policy rates.

The echo chamber effect resounds on financial markets: a social media alert system for meme stocks

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The short squeeze of Gamestop (GME) has revealed to the world how retail investors pooling through social media can severely impact financial markets. This work devises an early warning signal to detect suspicious users' social network activity, which might affect the financial market stability. Authors apply their approach to the subreddit r/WallStreetBets, selecting two meme stocks (GME and AMC) and two non-meme stocks (AAPL and MSFT) as case studies. The alert system is structured in two stpng; the first one is based on extraordinary activity on the social network, while the second aims at

identifying whether the movement seeks to coordinate the users to a bulk action. They run an event study analysis to see the reaction of the financial markets when the alert system catches social network turmoil. A regression analysis witnesses the discrepancy between the meme and non-meme stocks in how the social networks might affect the trend on the financial market.

Cryptocurrencies & Blockchain

A Comparison of Methods for Forecasting Value-at-Risk and Expected Shortfall of Cryptocurrencies

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Several procedures to forecast daily risk measures in cryptocurrency markets have been recently implemented in the literature. Among them, long-memory processes, procedures taking into account the presence of extreme observations, procedures that include more than a single regime, as well as quantile regression-based models have performed substantially better than standard methods in terms of forecasting risk measures. Those procedures are revisited in this paper, and their Value-at-Risk and Expected Shortfall forecasting performance are evaluated using recent Bitcoin and Ethereum data that includes periods of turbulence due to the COVID-19 pandemic, the third halving of Bitcoin and the Lexia class action. Additionally, in order to mitigate the influence of model misspecification and enhance the forecasting performance obtained by individual models, the authors evaluate the use of several forecast combining strategies. Their results, based on a comprehensive backtesting exercise, reveal that, for both cryptocurrencies, procedures taking into account the presence of extreme observations are preferable for forecasting both risk measures, outperforming long-memory models, regime-switching models, quantile regression-based models and combining strategies.

A General Framework for Impermanent Loss in Automated Market Makers

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The work provides a framework for analyzing impermanent loss for general Automated Market Makers (AMMs) and show that Geometric Mean Market Makers (G3Ms) are in a rigorous sense the simplest class of AMMs from an impermanent loss viewpoint. In this context, it becomes clear why automated market makers like Curve ([Ego19]) require more parameters in order to specify impermanent loss. Authors suggest the proper parameter space on which impermanent loss should be considered and prove results that help in understanding the impermanent loss characteristics of different AMMs.

Mixing Constant Sum and Constant Product Market Makers

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Two popular forms of automated market makers are constant sum and constant product (CSMM and CPMM respectively). Each has its advantages and disadvantages: CSMMs have stable exchange rates but are vulnerable to arbitrage and can sometimes fail to provide liquidity, while a CPMM can have large impermanent loss due to exchange rate changes but are always able to provide liquidity to participants. A significant amount of work has been done in order to get the best of both constant sum and constant product characteristics. Perhaps most the relevant to this paper is Stableswap, which has an "amplification coefficient" parameter controlling the balance between the two types of behavior. There is still much work to be done on these fronts. This paper presents multiple novel methods for mixing market makers and demonstrates new tools for designing markets with specific features.

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