Stevanovich Center
for Financial Mathematics
at the University Of Chicago

5727 South University Avenue
Chicago, IL 60637
773-834-8563

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Market Microstructure, Quantitative Trading,

High Frequency and Large Data

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Steve G. Stevanovich

Torben Andersen (Northwestern University)
Title: Intraday Trade Invariance in the Foreign Exchange Futures Market

Abstract: We examine a novel intraday invariance relation among trading activity variables across seven currencies in the foreign exchange futures market using high-quality transaction level data. It generalizes the intraday trading invariance (ITI) hypothesis developed in Andersen, Bondarenko, Kyle, and Obizhaeva (2015) by accounting also for the direct trading cost manifest in the bid-ask spread. The relation is cast as universal across time and assets, and it is therefore much more ambitious than prior proposed invariance relations, including the Mixture of Distributions Hypothesis (MDH). We find the ITI relationship to be robust and dramatically outperform the MDH. Interestingly, we observe a shift in the relation among the individual series around the imposition of a mandated tick size reduction. Likewise, we document robustness of the ITI relation to other strong external market shocks. Because the tick size changes occur at distinct time across currencies, and the shocks have differential impacts, they serve as pseudo-natural experiments to gauge the stability of the invariance relation. Our empirical implementation avoids serious endogeneity problems present in most prior tests of related invariance relationships. We further test the hypothesis that the ITI relation applies jointly to all FX contracts simultaneously. The results are sufficiently supportive to suggest that the relation provides a useful diagnostic on market stress and captures universal features of a dynamic market equilibrium. More broadly, we suspect that distinct institutional and regulatory environment across asset classes will imply heterogeneity in the relation that must be accommodated, at a minimum, through a different mean level of the market invariant quantity. (Joint work with Oleg Bondarenko, Eleni Gousgounis, and Esen Onur)

Federico Bandi (Johns Hopkins University)

Title: Conditional Spectral Methods

Abstract: We employ suitable matrix representations to express future values of covariance-stationary processes in terms of conditionally orthonormal frequency-specific basis. The representations lead to notions of frequency-specific conditional variance and conditional beta. The class of GARCH-M models is used to represent (i) the role of conditional variance in generating frequency-specific cycles in returns and (ii) the pricing of conditional variance fluctuations of alternative lengths. (Joint with Yinan Su)

Rong Chen (Rutgers University)

Title: CP Factor Model for Dynamic Tensors

Abstract: Observations in various applications are frequently represented as a time series of multidimensional arrays, called tensor time series, preserving the inherent multidimensional structure. In this paper, we present a factor model approach, in a form similar to tensor CP decomposition, to the analysis of high-dimensional dynamic tensor time series. As the loading vectors are uniquely defined but not necessarily orthogonal, it is significantly different from the existing tensor factor models based on Tucker-type tensor decomposition. The

model structure allows for a set of uncorrelated one-dimensional latent dynamic factor processes, making it much more convenient to study the underlying dynamics of the time series. A new high order projection estimator is proposed for such a factor model, utilizing the special structure and the idea of the higher order orthogonal iteration procedures commonly used in Tucker-type tensor factor model and general tensor CP decomposition procedures. Theoretical investigation provides statistical error bounds for the proposed methods, which shows the significant advantage of utilizing the special model structure. Simulation study is conducted to further demonstrate the finite sample properties of the estimators. Real data application is used to illustrate the model and its interpretations.

Carsten Chong (Columbia University)

Title: When frictions are fractional: Rough noise in high-frequency data

Abstract: The analysis of high-frequency financial data is often impeded by the presence of noise. This paper is motivated by intraday transactions data in which market microstructure noise appears to be rough, that is, best captured by a continuous-time stochastic process that locally behaves as fractional Brownian motion. Assuming that the underlying efficient price process follows a continuous Itô semimartingale, we derive consistent estimators and asymptotic confidence intervals for the roughness parameter of the noise and the integrated price and noise volatilities, in all cases where these quantities are identifiable. In addition to desirable features such as serial dependence of increments, compatibility between different sampling frequencies and diurnal effects, the rough noise model can further explain divergence rates in volatility signature plots that vary considerably over time and between assets.

Per Mykland (University of Chicago) and Lan Zhang (University of Illinois at Chicago)

Title: Nonparametric Observed Standard Errors for High Frequency Data

Abstract: High frequency financial data has become an essential component of the digital world, giving rise to an increasing number of estimators. However, it is hard to reliably assess the uncertainty of such estimators. The Observed Asymptotic Variance (observed AVAR) is a non-parametric (squared) standard error for high-frequency-based estimators. We have earlier developed such an AVAR with time-discretization and two tuning parameters (per dimension). The current paper shows that these two parameters are confounded, and one can move to a single tuning parameter. This is shown by passing to continuous time (which is natural since observations are irregularly spaced). We show that the new time-continuous observed AVAR is a limit of the original observed AVAR. We also obtain a central limit theory for the new time-continuous observed AVAR, and the latter permits a sharper definition of our standard error. The device is related to observed information in likelihood theory, but in this case it is non-parametric and uses the high-frequency data structure.

Andrew Patton (Duke University)

Title: Granular Betas and the Risk Premium Function

Abstract: We propose a measure of the local covariation between the returns on an asset and a factor across points in the support of the factor. These “granular betas” can be estimated using high frequency data, and generalize the up- and down-side betas of Ang, Chen and Xing (2006). Using the granular beta function to explain the cross-section of expected returns yields an estimate of the “risk premium function,” which generalizes the usual risk premium estimates obtained in a Fama and MacBeth (1973) regression. We show how to test whether the estimated risk premium function satisfies certain conditions (e.g., flatness and symmetry). Implementing the proposed methods on U.S. equity returns we find significant evidence against the (non-granular) CAPM, Fama-French, and Carhart models, and that the shape of the risk premium function varies across industries and across time. (Joint with Tim Bollerslev and Rogier Quaedvlieg)

Mark Podolskij (University of Luxembourg)

Title: High-dimensional volatility estimation under low rank constraints.

Abstract: In this talk, we develop a penalized realized variance (PRV) estimator of the quadratic variation of a high-dimensional continuous Ito semimartingale. We adapt the principle idea of regularization from linear regression to covariance estimation in a continuous-time high-frequency setting. We show that under a nuclear norm penalization, the PRV is computed by soft-thresholding the eigenvalues of realized variance (RV). It therefore encourages sparsity of singular values or, equivalently, low rank of the solution. We prove that our estimator is minimax optimal up to a logarithmic factor. We derive a concentration inequality, which reveals that the rank of PRV is--- with a high probability---the number of non-negligible eigenvalues of the quadratic variation. Moreover, we also provide the associated non-asymptotic analysis for the spot variance. We suggest an intuitive data-driven bootstrap procedure to select the shrinkage parameter. Our theory is supplemented by a simulation study and an empirical application. The PRV detects about three--five important factors in the equity market. This is consistent with most standard asset pricing models, where a limited amount of systematic factors driving the cross-section of stock returns are perturbed by idiosyncratic errors, rendering the quadratic variation---and also RV---of full rank.

Mathieu Rosenbaum (Ecole Polytechnique)

Title: AHEAD : Ad-Hoc Electronic Auction Design

Abstract: We introduce a new matching design for financial transactions in an electronic market. In this mechanism, called ad-hoc electronic auction design (AHEAD), market participants can trade between themselves at a fixed price and trigger an auction when they are no longer satisfied with this fixed price. In this context, we prove that a Nash equilibrium is obtained between market participants. Furthermore, we are able to assess quantitatively the relevance of ad-hoc auctions and to compare them with periodic auctions and continuous limit order books. We show that from the investors' viewpoint, the microstructure of the asset is usually significantly improved when using AHEAD. (Joint work with Joffrey Derchu, Philippe Guillot and Thibaut Mastrolia.)

Viktor Todorov (Northwestern University)

Title: Jumps, Leverage and Risk Premiums

Abstract: Jumps in asset prices are ubiquitous, yet the apparent high price of jump risk appears puzzling. In addition to direct price risks, however, jumps may also tend to trigger simultaneous changes in the conditional moments of asset returns and jumps in the stochastic volatility and/or jump intensity. We develop new model-free short-time expansions for two alternative risk-neutral variance measures, allowing us to more clearly delineate the role played by jumps in generating price and variance risks and the pricing of ``jump leverage effects'' in particular. Estimating the new variance expansions and risk-neutral measures based on short-dated S&P 500 index options, together with high-frequency S&P 500 returns for estimating the corresponding physical measures, we find that the jump leverage effect commands a nontrivial risk premium and contributes importantly to the much-studied variance risk premium. The empirically large jump leverage risk premium observed in the data may be rationalized economically by jumps in the conditional moments of the underlying fundamentals and/or changes in investors' risk aversion. (Joint work with Tim Bollerslev.)

Frederi Viens (Michigan State University)

Title: Three scales of high frequency: limit-order book modeling, path-dependent stochastic volatility pricing, and modeling uncertainty in long-term-bond portfolios.

Abstract: We will present an overview of three topics in the mathematical modeling of quantitative trading in finance, each with a separate notion of high-frequency data modeling. We first propose a limit-order book model that goes beyond generic stochastic modeling of market microstructure, by honoring the consistency of price movements upon arrivals of different order types. The objective in this problem is to take the point of view of a market maker working at high frequency, where the question is to maximize portfolio wealth given a fixed market share objective and a penalty for holding inventory; stochastic impulse control for market orders and optimal switching between LOB liquidity modes are used to manage inventory. Next, in continuous-time modeling, we describe a functional Ito formula which allows the computation, via path-dependent PDEs, of conditional expectations in highly non-Markovian models, such as functionals of fractional Brownian motion. An application is described for option pricing and hedging of volatility options in the fractional Heston and fractional Bergomi models, where the model assumptions are consistent with what has become known as rough volatility markets, a notion which applies only to relatively high-frequency market modeling. Finally, we will discuss the feasibility, or lack thereof, of managing portfolios of bonds with very long-term objectives. In this case, where institutional actors are involved, with portfolio maturities several decades away, high frequency is not about analyzing market microstructure. We will argue, in the mean-variance portfolio selection framework, under continuous-time stochastic interest-rate models, that a static strategy may sometimes be better suited than a dynamic one, given the reality of modeling ambiguity for very long-term bonds. These three topics represent collaborations respectively with Dr. Baron Law (New York Life), Prof. Jianfeng Zhang (U. Southern California), and Prof. Dennis Ikpe (Michigan State U./AIMS Cape Town) with Mr. Romeo Mawonike (Great Zimbabwe University). This presentation is dedicated to the memory of Mr. Mawonike, who passed unexpectedly on March 31, 2022.

Dacheng Xiu (University of Chicago)

Title: Inference on Risk Premia in Continuous-Time Asset Pricing Models

Abstract: We develop and implement asymptotic theory to conduct inference on continuous-time asset pricing models using individual equity returns sampled at high frequencies over an increasing time horizon. We study the identification and estimation of risk premia for the continuous and jump components of risks in this unified framework. Our results generalize the Fama-MacBeth two-pass regression approach from the classical discrete-time factor setting to a continuous-time factor model with general dynamics for the factors, idiosyncratic components and factor loadings, while accounting for missing data in the panel of test assets and estimated regressors from the first pass. Our empirical analysis with US equity sheds light on the salient role of jump risks in expected returns. (Joint work with Yacine Ait-Sahalia and Jean Jacod.)

Zhengjun Zhang (University of Wisconsin)

Title: Modeling and Decoupling Systemic Risk into Endopathic and Exopathic Competing Risks

Abstract: Identifying systemic risk patterns in geopolitical, economic, financial, environmental, transportation, epidemiological systems and their impacts is the key to risk management. This talk discusses a new nonlinear time series model: autoregressive conditional accelerated Fr'echet (AcAF) model and introduces two new endopathic and exopathic competing risk indecies for better learning risk patterns, decoupling systemic risk, and making better risk management. The paper establishes the probabilistic properties of stationarity and ergodicity of the AcAF model. Simulation demonstrates the efficiency of the proposed estimators and the AcAF model's flexibility in modeling heterogeneous data. Empirical studies on the stock returns in S&P 500 and the cryptocurrency trading show the superior performance of the proposed model in terms of the identified risk patterns, endopathic and exopathic competing risks, being informative with greater interpretability, enhancing the understanding of the systemic risks of a market and their causes, and making better risk management possible.
