



**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 & High Frequency Data**

### **Abstracts**



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Swagato Acharjee	Trading Considerations Around Market Close	<p>Exchanges advertise liquidity in the close auction book using order imbalance messages in an attempt to draw out liquidity and conduct an orderly auction. Member firms interact with the close auction via multiple order types with varying priorities of receiving an execution. In this paper, we present our findings on price impact of close auction imbalances. We observed larger price impact of publishing initial closing imbalances at NASDAQ vs NYSE. For NYSE stocks we found favorable price moves associated with offsetting imbalances at all times. We noticed significant natural liquidity unlocked by large imbalances for NYSE stocks. We also discuss how market participants can take these dynamics into account to execute orders optimally around market close.</p>
Federico Bandi	Spectral Factor Models	<p>We represent risk factors as sums of orthogonal components capturing fluctuations over different frequencies. The orthogonal representation is in the time domain, thereby facilitating applicability and economic interpretation with respect to frequency-domain analogues. The representation leads to novel spectral factor models in which systematic risk is allowed (without being forced) to vary across different frequencies. Frequency-specific systematic risk is captured by a notion of spectral beta. Using the orthogonal representation, we express the classical beta as a linear combination of spectral betas without cross-beta terms. Asset allocation is employed as an economic metric to evaluate spectral factor models: we show that specifications in which systematic risk is permitted to change across frequencies consistently lead to portfolios with lower out-of-sample variance relative to their counterparts in which systematic risk is stable across frequencies. In essence, we introduce easily-applicable, time-domain methods to explore the role of frequency as an element of risk. We illustrate how the methods may lead to dimension reduction in the factor space and helpful economic interpretability.</p> <p>Joint work with Shomesh Chaudhuri, Andrew Lo, and Andrea Tamoni</p>
Paul Besson	The benefits of Periodic Auctions Beyond Dark Trading Caps in Europe	<p>Initially designed as a better alternative than Dark trading, the success of Periodic Auctions has spread out across all European stocks. On capped stocks, their market share rose from 1% to 4.5% between early March and September 2018. Nevertheless, on uncapped stocks Periodic Auctions doubled in popularity from 0.75% to 1.5% over the same period. Periodic Auctions volume curve profiles are similar to those of Lit trades over the day. We show that trading intensity diminishes after a Periodic Auction trade, while it increases after a Dark trade. These findings are based on future trade time observations, as well as on future volume, or number of trades per second after a Lit, a Dark or a Periodic Auction trade. The random auction end time mechanism prevents adverse selection as shown by the price reversion. In Lit and Dark trading, passive buy trades are followed by a strong drop in midpoint due to adverse selection by the aggressive sellers. In contrast, Periodic Auction trades show almost no sign of adverse selection. Based on our trades we show that Periodic Auction participation mitigates the market impact.</p>

Zongwu Cai	Inferences for Varying-Coefficients Forward-Backward Diffusion Models	<p>This paper studies forward-backward stochastic differential equation models in continuous time setting with nonstationary time series data, allowing also for stationary data. A time-varying coefficients forward-backward diffusion model is considered, kernel estimations of the coefficients are obtained, and large sample theory of the coefficients are deduced by borrowing the method in Phillips, Li and Gao (2017). A functional-generator backward diffusion model is also considered, kernel estimations of the functional generators are obtained, and asymptotic behavior of the generator is deduced by borrowing the method in Cai, Li and Park (2009). As applications in finance, one can identify the Black-Scholes model and the Chen-Epstein model by the time-varying backward diffusion models, and identify linearity of generator and the stochastic differential utility by the functional-generator backward diffusion models. Empirical analyses will be shown later.</p> <p>Joint with Weihuan Huang, Shandong University</p>
Álvaro Cartea	Latency in Electronic Markets	<p>Latency is the time delay between an exchange streaming market data to a trader, the trader processing information and deciding to trade, and the exchange receiving the order from the trader. Liquidity takers face a moving target problem as a consequence of their latency in the marketplace. They send market orders with a limit price that aim at a price and quantity they observed in the limit order book (LOB), and by the time their order is processed by the exchange, prices could have worsened, so the order may not be filled, or prices could have improved, so the order is filled at a better price. We provide three models to include latency in optimal trading for liquidity takers. We compute the costs of improving the marksmanship of liquidity taking strategies and show the tradeoff between certainty in execution and the costs of reducing the adverse effects of latency.</p> <p>Joint work with Sebastian Jaimungal (U. Toronto) and Leandro Sanchez-Betancourt (U. Oxford)</p>
Hongsong Chou	Case Studies on Machine Learning and Trading Research	<p>Machine learning techniques have been widely used in trading strategy design and market microstructure research by many practitioners. In this talk, I will present a few case studies based on personal experiences in selected Asia-Pacific markets. In addition, I will discuss both potentials and hurdles for large scale applications of machine learning techniques in trading practices and microstructure research.</p>
Khalil Dayri	Practical Considerations for Trading in Dark Pools	<p>We go over some previously proposed models for trading in dark pool and explore their strengths and weaknesses from a practical perspective. We also showcase stylized facts relating to trade arrivals and price movements on different dark pools and make the argument that simpler optimization methods coupled with statistical estimators are preferred in a sell side trading environment and lead to more interesting options, trading styles and of course products.</p>

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Dobrislav Dobrev	High-Frequency Cross-Market Trading: Model Free Measurement and Applications	<p>We propose a set of intuitive model-free measures of cross-market trading activity based on publicly available trade and quote data with sufficient time stamp granularity. By virtue of capturing the offset at which co-activity peaks, as well as its magnitude and dispersion, the measures allow us to shed new light on the distinct features of the high-frequency cross-market linkages in US Treasury and equity markets. First, the measures avoid reliance on noisy high-frequency return series often used in the literature and demonstrate sharp identification of the prevailing lead-lag relationships between trading activity across markets. Second, we show how the measures can be used to examine price impact and liquidity provision in (near) arbitrage linked markets. In particular, we provide new evidence suggesting that price discovery in US Treasury and equity markets primarily takes place in futures rather than cash markets. We further show that our measures of cross-market activity are closely linked with observed market volatility even after controlling for commonly used measures of market activity such as trading volume and number of transactions. Finally, we use our measures to draw an important distinction between the 2010 US equity market flash crash and the 2014 US Treasury market flash rally underscoring the important role played by high-speed cross-market activity in maintaining the no-arbitrage price link between futures and cash markets during periods of significant market stress. Overall, our empirical findings suggest that accounting for cross-market trading activity is important when studying the volatility and liquidity of US Treasury and equity markets.</p> <p>Joint work with Ernst Schaumburg</p>
	Nikolaus Hautsch	Limits to Arbitrage in Markets with Stochastic Settlement Latency

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Jean  
Jacod

High-Frequency  
Statistics for a  
Semimartingale with  
Jump Activity Varying  
with Time

When a discretely observed process has jumps with infinite activity, and in particular when the jumps are not summable, so far all available statistical methods for estimating the spot or integrated volatility, or the degree of jump activity, or the spot or integrated intensity of jumps, suppose that the degree of activity of jumps, also called Blumenthal-Gettoor index, is a constant. In this talk we propose a method which allows the degree of activity to vary with time, and even to be a (reasonable) stochastic process by itself. In this setting, we sketch how one can estimate the spot and integrated volatility, or the spot degree of activity and the associated intensity. The method is based on various versions of the empirical characteristic function of the increments of the observed process.  
Joint work with Viktor Todorov

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Kiseop  
Lee

Systemic Risk in  
Market  
Microstructure of  
Crude Oil and  
Gasoline Futures  
Prices: A Hawkes  
Flocking Model  
Approach

We propose a novel class of Hawkes-based model that assesses two types of systemic risk in high-frequency price processes: the endogenous systemic risk within a single process and the interactive systemic risk between a couple of processes. We examine the existence of systemic risk at a microscopic level via an empirical analysis of the futures markets of the West Texas Intermediate (WTI) crude oil and gasoline and perform a comparative analysis with the conditional value-at-risk as a benchmark measure of the proposed model. Throughout the analysis, we uncover remarkable empirical findings in terms of the high-frequency structure of the two markets: for the past decade, the level of endogenous systemic risk in the WTI market was significantly higher than that in the gasoline market. Moreover, the level at which the gasoline price affects the WTI price was constantly higher than in the opposite case. Although the two prices interact with each other at the transaction-unit level, the degree of relative influences on the two markets, that is, from the WTI to the gasoline and vice versa, was very asymmetric, but that difference has reduced gradually over time.  
Joint work with Hyun Jin Jang and Kyungsub Lee

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Jia Li	Measuring China's Stock Market Sentiment	<p>This paper develops textual sentiment measures for China's stock market by extracting the textual tone of 60 million messages posted on a major online investor forum in China from 2008 to 2018. We conduct sentiment extraction by using both conventional dictionary methods based on customized word lists and supervised machine learning methods (support vector machine and convolutional neural network). The market-level textual sentiment index is constructed as the average of message-level sentiment scores, and the textual disagreement index is constructed as their dispersion. These textual measures allow us to test a range of predictions of classical behavioral asset pricing models in a unified empirical setting. We find that the textual sentiment can significantly predict market return, exhibiting short-run under-reaction and long-run reversal. This effect is more pronounced for small stocks, and is stronger under higher investor attention and during more volatile periods. We also find that the textual sentiment exerts a significant and asymmetric impact on future volatility. Finally, we show that trading volume will be higher when the textual sentiment is unusually high or low, and when there are more differences-of-opinion as measured by our textual disagreement. Based on a massive textual dataset, our analysis provides support for the noise-trading theory, the limits-to-arbitrage argument, as well as predictions from limited-attention and disagreement models.</p> <p>Joint work with Yun Chen, Yan Shen, Jingyi Wang, Zhuo Huang</p>
Joshua Mollner	Contracting for Financial Execution	<p>Financial contracts often specify reference prices whose values are undetermined at the time of contracting, which makes them prone to manipulation. To study such situations, we introduce a stylized model of financial contracting between a client, who wishes to trade a large position, and her broker. We find that a simple contract based on the market volume-weighted average price (VWAP) emerges as the unique optimal solution to this principal-agent problem. This result explains the popularity of guaranteed VWAP contracts in practice and also suggests considerations for the optimal design of financial benchmarks.</p> <p>Joint work with Markus Baldauf and Christoph Frei</p>
Kjell Nyborg	Repo rates and the collateral spread puzzle	<p>Repo rates frequently exceed unsecured rates in practice. As an explanation, this paper derives a constrained-arbitrage relation between the unsecured rate, the repo rate, and the illiquidity adjusted expected rate of return of the underlying collateral. The theory is based on unsecured borrowing constraints in the market for liquidity. Repos and security cash-market trades are alternative means to get liquidity. Collateral spreads (unsecured less repo rate) can turn negative if borrowing constraints tighten, unsecured rates spike down, or from a depressed and illiquid security market. The constrained-arbitrage theory sheds light on the evolution of collateral spreads over time.</p>

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Andrew Patton	What You See is Not What You Get: The Costs of Trading Market Anomalies	Is there a gap between the profitability of a trading strategy “on paper” and that which is achieved in practice? We answer this question by developing a general technique to measure the real-world implementation costs of financial market anomalies. Our method extends Fama-MacBeth regressions to compare the on-paper returns to factor exposures with those achieved by mutual funds. Unlike existing approaches, our approach delivers estimates of all-in implementation costs without relying on parametric microstructure models or explicitly specified factor trading strategies. After accounting for implementation costs, typical mutual funds earn low returns to value and no returns to momentum. Joint with Brian Weller
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Emil Stoltenberg	Volatility and intensity	When studying models and estimators in the setting of high-frequency data, simplifying assumptions are typically imposed on the relation between the observation times and the observable process. In this paper we study a certain form of endogeneity of the observation times, namely that they depend on non-observable spot processes. The prototypical example is that of a stochastic volatility model observed at times which are in part determined by the stochastic volatility process. We introduce an estimator of the quadratic covariation between two spot process semimartingales, and apply this estimator to the problem of assessing the relation between the spot volatility and the intensity process governing the observations times. Consistency of this estimator is proved, and its convergence rate is derived. In an empirical study of the Apple stock over 21 trading days we find indications of a correlation between the spot volatility and the observation times. Joint work with Per Mykland and Lan Zhang
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George Tauchen	Variation and Efficiency of High-Frequency Betas	The paper studies the efficient estimation of betas from high-frequency return data on a fixed time interval. Under an assumption of equal diffusive and jump betas, we derive the semiparametric efficiency bound for estimating the common beta and we develop an adaptive estimator that attains the efficiency bound. We further propose a Hausman type test for deciding whether the common beta assumption is true from the high-frequency data. In our empirical analysis we provide examples of stocks and time periods for which a common market beta assumption appears true and ones for which this is not the case. We further quantify empirically the gains from the efficient common beta estimation developed in the paper. Joint work with Jia Li, Duke University, Viktor Todorov, Northwestern University, Congshan Zhang, Duke University
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Allan Timmermann	Cash Flow News and Stock Price Dynamics	<p>We develop a new approach to modeling dynamics in cash flow data extracted from daily firm-level dividend announcements. We decompose the daily cash flow news series into a persistent component, jumps, and temporary shocks. Empirically, we find that the persistent cash flow growth component predicts future dividend growth and is significantly positively correlated with stock market returns. Cash flow dynamics have sizeable and long-lasting effects on the volatility and jump probability of stock returns through an uncertainty transmission channel. Finally, we find that news about the persistent cash flow growth component is correlated with a variety of cross-sectional risk factors.</p> <p>Joint with Davide Pettenuzzo and Riccardo Sabbatucci</p>
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Kevin Webster	Revisiting the Obizhaeva and Wang model	<p>We study two new applications of the Obizhaeva and Wang model using a new, simplified proof method. The first application covers the delta hedging of options in the presence of transient price impact. The second application solves the mean field game arising from the model.</p>
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Dacheng Xiu	Predicting Returns with Text Data	<p>We introduce a new text-mining methodology that extracts sentiment information from news articles to predict asset returns. Unlike more common sentiment scores used for stock return prediction (e.g., those sold by commercial vendors or built with dictionary-based methods), our supervised learning framework constructs a sentiment score that is specifically adapted to the problem of return prediction. Our method proceeds in three steps: 1) isolating a list of sentiment terms via predictive screening, 2) assigning sentiment weights to these words via topic modeling, and 3) aggregating terms into an article-level sentiment score via penalized likelihood.</p> <p>We derive theoretical guarantees on the accuracy of estimates from our model with minimal assumptions. In our empirical analysis, we text-mine one of the most actively monitored streams of news articles in the financial system---the Dow Jones Newswires---and show that our supervised sentiment model excels at extracting return-predictive signals in this context. First, the model selects a list of positive and negative sentiment words that is clearly interpretable and intuitive. Moreover, a simple trading strategy demonstrates that our news sentiment scores outperform scores from a widely-used commercial vendor in predicting future price moves (by a large margin).</p> <p>Jointly with Tracy Ke and Bran Kelly</p>

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Yong Zeng	Bayesian Inference via Filtering Equations for Financial Ultra-High Frequency Data	<p>We propose a general partially-observed framework of Markov processes with marked point process observations for ultra-high frequency (UHF) transaction price data, allowing other observable economic or market factors. We develop the corresponding Bayesian inference via filtering equations to quantify parameter and model uncertainty. The methodology has three ingredients. First, we derive filtering equations to characterize the evolution of the likelihoods, the posteriors, and the Bayes factors. Given the computational challenge, we prove a weak convergence theorem, which provides a recipe for constructing consistent, easily-parallelizable, recursive algorithms by employing the Markov chain approximation method. The recursive algorithms are capable of calculating the fundamental statistical characteristics and implementing the Bayesian inference for streaming UHF data. The general theory is illustrated by specific models built for U.S. Treasury Notes transactions data from GovPX. The empirical results show that both information-based and inventory management-based motives are significant factors in the trade-to-trade price volatility.</p> <p>Joint work with Grace Xing Hu and David R. Kuipers</p>
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Zhengjun Zhang	Mark to Market Value at Risk	<p>Financial risk management has been overwhelmed by applications and research of value at risk (VaR) in daily practice mainly due to its simple form and easily interpretable feature. Yet, its serious drawback of underestimating an asset's market risk has been noticed in numerous applications, and many alternative risk measures have been proposed in the literature. Among all existing alternative risk measures, it is hard to find one that a financial institution whose portfolio has multiple settlements before the end of holding period uses to internally perform risk assessment. We propose a new risk measure termed mark to market value at risk (MMVaR) for settlement being taken daily during the holding period. MMVaR is a natural alternative risk measure to VaR as it is a direct generalization of VaR. It not only maintains easily interpretable feature held by VaR, but also better computes an asset's market risk in a financial institution having daily account settlements. We show that MMVaR is superior to VaR using simulation examples and real data. In real data analysis, we find that risks calculated using MMVaR are about 20% higher than risks calculated using classical VaR, which provides an evidence proof of Basel III's new capital adequacy ratio requirement, and hence it can become an implementable daily risk measure.</p> <p>Joint work with Yu Chen and Zhicheng Wang</p>
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