FAKULTÄT FÜR MATHEMATIK
Dekan Univ.-Prof. Dr. Radu Ioan Boţ

Einladung zur öffentlichen Defensio

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Thema der Dissertation

Signature methods and polynomial McKean-Vlasov equations for financial modeling

Abstract:
The aim of this thesis is to explore novel approaches to modeling and learning from the dynamics of financial markets. In that, the focus lies in incorporating path-dependence and distributional dependencies into the description of financial systems.

The first problem we tackle is portfolio optimization using streams of market data in the context of Stochastic Portfolio Theory (SPT). We extend functionally generated portfolios originally introduced in SPT to the notion of linear path-functional portfolios. The latter are constructed via certain linear combinations of non-anticipative path-functionals serving as feature maps, of which a special case are elements of the signature of paths of relevant factors. We study theoretical aspects of signature portfolios such as universal approximation of any continuous path-dependent portfolio and portfolio selection problems such as expected log-utility maximization and mean-variance type optimizations. We show that both take a convex quadratic form. We illustrate these theoretical findings with various numerical experiments. On one hand, we demonstrate in simulated markets that the trained signature portfolios are indeed remarkably close to the growth-optimal portfolios. On the other hand, we train signature portfolios using real market data of the NASDAQ, S&P500 and SMI, and find that the learned portfolios out-perform the respective market portfolio in almost all cases, over the considered out-of-sample period, even under transaction costs.

In a second line of research regarding path-dependence, we develop a path-dependent stochastic volatility model and calibrate it to VIX and SPX implied volatility surfaces jointly. To achieve both tractability and universality, we propose to model the volatility process via the signature of an underlying polynomial process. This enables us to derive closed form expressions for the VIX and SPX index, respectively. Moreover, we show that the calibration task can be split into an offline sampling and online learning phase, that Fourier

pricing techniques are available and propose variance reduction techniques in the case of Monte-Carlo simulations. We consolidate these findings to calibrate the model to real market data, and find that the calibrated implied volatilities are indeed highly accurate.

Finally, we address distributional dependencies in the evolution of financial systems by introducing so-called polynomial and affine McKean-Vlasov stochastic differential equations (SDEs). We study them using the theory of time-inhomogeneous polynomial and affine processes. In the polynomial case, we let the dependence on the law of the SDEs coefficients break down to a dependence on the (conditional) moments of the process, emulating the form of a standard polynomial process. A special case of such McKean-Vlasov SDEs were previously used to model capitalization curves in the context of SPT. In the affine case, we can allow the coefficients to depend on the characteristic function more generally. Both approaches allow us to study solutions of the SDEs in a Markovian setting and to establish new existence and uniqueness results which are, to the best of our knowledge, not obtainable using standard techniques.

Prüfungssenat

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Zeit und Ort

Freitag, 29. November 2024, 10:30 Uhr

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