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REPORT OF A THESIS ADVISOR

Master's thesis title: "Information flows and their role in complex systems"

Candidate: Zlata Tabachová

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Assessment: A (výborně)

It is a pleasure to report on Master's Thesis of Zlata Tabachová. Ms. Tabachová worked under my supervision during the academic years 2017-2021. In that time she focused her attention on issues related to the origin of heavy-tailed distributions in financial and other complex systems with a particular emphasize on Rényi entropy and ensuing Rényi information flow.

The use of heavy-tailed distributions in finance was pioneered by B. Mandelbrot in early 1970's and later on substantially promoted by H.E. Stanley, D. Sornette and L.P. Kadanoff in mid 1990's, even though the incentives can be traced back to seminal works of V. Pareto (in 1920'). The specificity in working with heavy-tailed distributions lies in the fact that the Central Limit Theorem alongside with the usual methods of estimation theory and substantial part of statistical physics cannot be applied. Theoretical qualification for such a "non-canonical" behavior can be provided, e.g., by means of the generalized Central Limit Theorem of P. Lévy, by theory of infinitely divisible distributions or by theory of critical phenomena.

In her work was Ms. Tabachová inspired not only by classical works of A. Rényi (Rényi entropy), H. Kantz and T. Schreiber (non-linear time series analysis), C. Granger (causality) but also by a number of original recent papers. She approached the subject of her Thesis with a wide knowledge of prerequisite mathematical concepts and numerical techniques. Thesis material also undoubtedly benefited from an expertise, which Ms. Tabachová has gained during her internships in various bank institutions.

The work itself is well structured and basic concepts are easy to grasp. In Chapter 0 some information about the organization of the Thesis is provided.

Chapter 1 gives some necessary mathematical background in both probability and information theory. Beside a standard material (e.g., probability axiomatization), Ms. Tabachová also discusses such advanced topics as fractal and multifractal measures or generalized entropies. In Chapter 2 she first provides an accessible introduction to the concept of Rényi's information measure and then she extends her reasoning to the ensuing Rényi's transfer entropy. Chapter 3 is devoted to the issue of causality with a particular emphasize on Granger causality. This chapter forms a basic interpretational frame for discussions of the role of transfer entropies in data-driven causal inference that are further presented in Chapter 5. Chapter 4 is dedicated to some basic stochastic models of financial markets such as ARCH, GARCH or option pricing model of Black and Scholes. Particularly GARCH models are then used in Chapter 5 in numerical simulations of entropic transfers. In order to illustrate further the pertinency of Rényi entropy, Ms Tabachová discusses in Chapter 4 various risk management strategies, e.g., Markowitz portfolio diversification (Nobel price 1990) and minimum Rényi entropy portfolio. In particular, the later yields the better risk-return-turnover than classical Markovitz portfolio theory. First part of Chapter 5 presents a brief survey of state-of-the-art in the field of data-driven entropy estimation. In the second part of Chapter 5 this is then employed in an explicit evaluation of Rényi information flow in three types of bivariate time series — pink noise time series, coupled Rössler system time series and coupled GARCH time series. This part belongs to the most original part of the Thesis. In fact, results related to Rényi information flow between coupled GARCH processes were published in journal MDPI. We are currently finishing a paper on Rényi information flow between two coupled Rössler system. The paper should hopefully appear in journal Entropy. Thesis closes with Chapter 6 where a brief summary of results is presented and

All in all, Master Thesis of Ms. Tabachová has in my opinion a very high quality. It offers an interesting and in many respects original selection and discussion of topics that are potentially relevant, e.g., in a systematic study of a causation issue in bivariate time series in terms of (phenomenologically relevant) heavy tailed distributions. Key aspects of the problems, such as theory of Rényi entropies and transfer entropies are worked out logically and clearly. Theory of heavy tailed stochastic processes is conceptually and technically demanding endeavor within the steadily growing field of Quantitative Finance and I am sure that expertise gained by Ms. Tabachová will be beneficial to her in the years to come.

Petr Jizba