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DATE 13.03.2025	OUR REFERENCE	YOUR LETTER DATED	YOUR REFERENCE
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Subject: Habilitation dissertation of Vladimír Holý

Dear Sir,

For the habilitation of Mgr. Vladimír Holý, Ph.D., I have read with much interest his habilitation thesis (September 2024) which contains an impressive number of eight articles/papers on score-driven (or observation-driven) dynamic models. In the first chapter of his research, Dr. Holý has developed a user-friendly computer implementation (in R) of tools relevant for the modelling, analysis, and forecasting of time series based on score-driven dynamic models. This is very valuable work for the community of score-driven researchers and for applied workers. The relevance of this work is well described in the thesis of Dr. Holý: *The class of score-driven models includes many well-known time series models. For instance, the score-driven model based on the normal distribution with time-varying mean closely resembles the autoregressive moving average (ARMA) model, while the score-driven model based on the normal distribution with time-varying mean closely resembles the autoregressive moving volatility corresponds to the generalized autoregressive conditional heteroskedasticity (GARCH) model. Expanding beyond the normal distribution to incorporate other probability distributions, however, opens the door to the development of entirely novel models suitable for a wide array of univariate and multivariate data types, including non-negative, count, integer, and ranking data.*

In the second chapter, an innovative score-driven model designed for dynamic rankings, utilizing the Plackett-Luce distribution, is introduces. It is based on the Luce's choice axiom, with time-varying worth parameters. An interesting application is presented for the outcomes of the Men's Ice Hockey World Championships, while other illustrations are also explored. This contribution is novel and of importance as there is limited existing literature on the dynamics of ranking data. In the third chapter, the application of Ice Hockey is further developed. The model is extended with several factors including the team past-performance, the potential home advantage of hosting the game, the results from earlier tournaments, players' physical attributes, and players' experience. The empirical findings are surely of interest to quantitative sport analysists.

In the fourth chapter, the use of the score-driven ranking model in the context of two-stage data envelopment analysis (DEA) is explored. DEA follows efficiency measurements with a second-stage regression analysis using efficiency scores as dependent variables and contextual variables as

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independent variables. Dr. Holý proposes an alternative approach to the second stage of DEA by using score-driven rankings instead of efficiency scores. This is an interesting and creative development which is nicely illustrated for assessing research efficiency in higher education in the EU. In the fifth paper, a truly interesting problem of clustering in high-frequency financial prices is studied. A particular novel discrete score-driven model for prices is developed. The model leverages a dynamic mixture of double Poisson distributions that accommodates both dynamic volatility and the evolving proportions of agent types. The empirical study for 30 Dow Jones stock prices reveals different impacts on prices and volatilities.

The sixth paper presents an innovative approach to modelling high-frequency time series of prices, addressing their unique characteristics such as irregularly spaced observations, simultaneous transactions, discrete price levels, and the presence of market microstructure noise. The model is based on the zero-inflated Skellam distribution but with a newly proposed overdispersion parametrization. Dr. Holý has further incorporated time-varying volatility within the score-driven framework, and has filtered market microstructure noise using a moving average component. This extensive model is impressive and the empirical results that are presented are convincing. This model is valuable for measuring daily realized volatility as a parametric alternative to realized kernels and similar measures, filtering both diurnal patterns and market microstructure noise

The seventh paper employs the zero-inflated negative binomial distribution with score dynamics, incorporating mean, overdispersion, and zero-inflation parameters, all of which are treated as time-varying. This score-driven model enables the distinction between the processes generating split and independent transactions. This study establishes the invertibility of the score filter and verifies that sufficient conditions hold for the consistency and asymptotic normality of the maximum likelihood of the model parameters. This is impressive work.

The eighth paper introduces a score-driven ACD model for queueing systems. The results underscore the economic imperative of correctly modelling arrival dependencies, offering invaluable insights for process simulations, optimization, and quality assessment.

From these eight papers, Dr. Holý has been able to publish six papers in highly respectable journals. This is very convincing. Four papers are single-author and two of these are published, one in the widely recognized journal *Annals of Operations Research*, and one in the journal *Operations Research Perspectives*.

Based on his publication record, Dr. Holý has demonstrated the ability to conduct research independently. I am convinced he can guide and supervise junior scholars, such as PhD students. Thus, I can strongly recommend that Dr. Holý be promoted to the rank of Associate Professor at the Department of Econometrics, at Prague University of Economics and Business.

Please do not hesitate to contact me if you need any further information.

Yours sincerely,

Siem Jan Koopman Professor of Econometrics