Research proposal

Scientific supervisor: Giacomo Bormetti

SSD: SECS-S06

Duration: 24 (twenty four) months

Co-Funding: 80% from PRIN2020

Title: Score-driven time-varying parameter models for high-frequency data and temporal networks

The position is co-funded by the Italian Ministero dell'Università e Ricerca, PRIN2020 Project Code: 20205J2WZ4_004 whose main objective is the development of an observation-driven approach to dynamic models in Economics and Finance.

In this research project, we aim to develop new dynamic models with time-varying parameters based on the recently introduced Score-Driven (SD) approach of Creal et al. (2013) and Harvey (2013). SD models represent a general class of observation-driven models (Cox, 1981) where parameters evolve over time based on past observations. We argue that the adoption of SD models to describe the dynamics of socio-economic systems is particularly convenient for two main reasons: (i) economically, contrary to existing approaches where parameters follow a stochastic process with random and exogenous shocks, SD models might allow the evolution of the parameters to be driven by actual realized past shocks, thus opening the possibility to gauge the impact of observed shocks on the future evolution of the model parameters; (ii) computationally, since SD models are susceptible to straightforward maximum likelihood estimation, they are able to effectively deal with high-dimensional problems and large amount of data.

This project comprises two lines of research:

OB1. *Testing and forecasting of temporal networks with dynamic node dependencies*

We aim to propose a class of dynamic models for temporal networks. This will allow us to investigate how links form, how persistent over time links are, and how they change in response to the state of the network and/or to exogenous covariates. In addition, to cope with possible non-stationarity or regime changes, we aim to develop a time-varying parameter model which can be efficiently estimated in real time, allowing us to produce forecasts of future network states. To this end, we will consider a popular class of statistical models for networks, known as Exponential Random Graph Models (Robins et al. 2007), for which the log probability mass function is proportional to a linear combination of certain network statistics. In order to generalize the model for a temporal network, we will assume that the coefficient of the linear combination follows an SD dynamics. The advantages of this approach to temporal networks are several: a) using the so-called prediction error decomposition, the likelihood can be readily expressed in closed form; b) suitable regularity conditions ensure the consistency and asymptotic normality for the maximum likelihood estimators of the parameter values; c) SD models allow for a test based on Lagrange Multipliers discriminating whether the observations are better described by a model with time-varying parameters or static ones. The specifications that our project plans to explore lend themselves to interesting perspectives, among which testing for the significance of the time-variation and possible dependence on exogenous covariates, and forecasting. First steps in these directions have been taken in Di Gangi et al. (2019, 2022).

OB2. *Time-varying models for market microstructure and high-frequency data*

The management of asset trading transaction costs represents a crucial concern in implementing investment decisions. When executing an order, there is a trade–off between immediacy and market risk. Both translate into cost components, since the revelation of trading intention adversely affects asset prices. Most of the literature assumes that liquidity, i.e the response of price to trades and orders, is constant or evolves slowly with time. On the contrary, liquidity is dynamic, both because of the strong seasonal behaviour of market variables (volatility, spreads, volume) at intraday level and of the fact that price impact is a latent and fluctuating quantity. There is room to question the adequacy of the standard dynamic models casted on the assumption of constant parameter values, especially those related to price impact. In addition, it is quite natural to think about the interplay between trades and quotes as an adaptive system, which reacts to the disclosing information. We aim at unravelling these aspects by means of SD models, since they are naturally suited for this purpose. The score of the conditional log-likelihood drives the evolution of time-varying parameters. Then, at the same time, we are able: i) to drop the unrealistic assumption of constant parameter values; ii) to inject in the model the non-linear dependence of the score on both observations and time-varying parameters; iii) to model in an effective way the response of the market to the revealing trades and quotes; iv) to filter in real time the time dependent behaviour of market liquidity; v) to investigate the transient and permanent future impact of orders by means of non-linear response functions. We plan to investigate two classes of processes: (1) a cointegrated VAR model with time-varying parameters of ask and bid quotes, as well as several levels of depth volume on both sides of the market, inspired by Hautsch and Huang (2012); (2) a structural bivariate VAR model of trades and quote revisions with time-varying autoregressive coefficients, innovation covariances and mixing matrices, inspired by Hasbrouck (1991).
Finally, the availability of big datasets of intraday high-frequency data has shifted the attention towards the multivariate modelling of the market dynamics, a topic of huge interest in risk assessment and portfolio construction. A first step in the direction of high-frequency market microstructure modelling has been taken in Buccheri et al. (2021), where the evolution of the logarithmic observed trade price has been investigated disentangling the dynamics of the fundamental price from the contamination of the microstructure noise in presence of asynchronicity. As a step forward we plan to extend the analysis to different order book variables, such as the logarithmic mid- and micro-prices.

The methods used in the project are Time Series and Data Analysis, Statistical Modelling of Complex Systems, Monte Carlo Methods for Economics and Finance, Complex Network Theory.

Plan of activities

The role of the researcher will be the development and analysis of new statistical models for high-frequency data from market microstructure and temporal networks, estimation of the model parameters, and use in simulation for in-sample and out-of-sample analyses.
Months 1-2: literature review. Months 3-6: critical analysis of the methodologies. Months 7-24: development of new solutions, numerical investigation in a controlled setting (Monte Carlo), and empirical analysis of the data.

The activity of dissemination of results will be carried out by giving seminars in Italian and international universities and participating as a speaker to the major conferences of the field.

List of references

Buccheri, G., Bormetti, G., Corsi, F., and Lillo, F. (2021). A Score-Driven Conditional Correlation Model for Noisy and Asynchronous Data: An Application to High-Frequency Covariance Dynamics. J. Bus. Econ. Stat. 39(4), 920-936.

Cox, R., et al. (1981). Statistical analysis of time series: Some recent developments. Scandinavian Journal of Statistics, 93-115.

Creal, D. Koopman, S. J., and Lucas, A. (2013). Generalized autoregressive score models with applications. J. Appl. Econ. 28(5), 777-795.

Di Gangi, D., Bormetti, G., and Lillo, F. (2019). Score-Driven Exponential Random Graphs: A New Class of Time-Varying Parameter Models for Dynamical Networks. arXiv:1905.10806.

Di Gangi, D., Bormetti, G., and Lillo, F. (2022). Score Driven Generalized Fitness Model for Sparse and Weighted Temporal Networks. arXiv: 2202.09854.

Harvey, A. C. (2013). Dynamic Models for Volatility and Heavy Tails. Cambridge University Press. Econometric Society Monographs.

Hasbrouck, J. (1991). Measuring the information content of stock trades. J. Financ. 46(1), 179-207.

Hautsch, N., and Huang, R. (2012). The market impact of a limit order. J. Econ. Dyn. Control. 36(4), 501-522.

Robins, G., Pattison, P., Kalish, Y., and Lusher, D. (2007). An introduction to exponential random graph (p*) models for social networks, Social Networks, 29(2), 173-191.