DOCTOR OF PHILOSOPHY IN MANAGEMENT

METHODS OF ANALYZING STRUCTURAL BREAKS IN MULTIVARIATE TIME SERIES: APPLICATIONS TO FINANCIAL DATA

By

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INDIAN INSTITUTE OF MANAGEMENT BANGALORE

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To my parents - the stationary in the volatile world

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ABSTRACT

Our focus in this thesis is to contribute to the extant literature by proposing two methods of structural break detection in a multivariate time series based on two dimension reduction techniques: t-distributed Stochastic Neighbor Embedding (t-SNE) and Independent Component Analysis (ICA). We also apply cumulative sums based Binary Segmentation to detect the location of breakpoints. Both the methods proposed by us prove to be efficient when compared with a few existing techniques of changepoint detection. Performance of each of the methods is compared based on the values of Rand Index (RI), Adjusted Rand Index (ARI), average time take taken by the method (ATT) and the number of changepoints estimated (ACP) by each procedure.

Based on simulation studies, it is observed that the t-SNE based method is better than the several existing ones in terms of accuracy as well as the time taken. It rightly detects a break when there is a change in the generalized autoregressive conditional heteroskedastic (GARCH) structure of the time series. For generalization, we consider both Gaussian and student's t as conditional distributions for GARCH models. A change in the GARCH structure is very apparent in a financial time series and our method successfully detects the break with better precision. We administer the t-SNE based breakpoint location method on a real data set of five cryptocurrencies to fathom its volatility dynamics. First, our method rightly ascertains the location of changepoints which coincides with the cryptocurrency boom of 2017 and the COVID-19 pandemic. This divides the time series into three subsamples (SS1, SS2 and SS3). To add to that, we also model the conditional variances of this dataset using EGARCH models augmented by several heavy

tailed residual distributions. Residual distributions play an important role in modelling the data appropriately for better forecasting. It is observed that for SS2 which is longer in duration and has low volatility, Exponential GARCH (EGARCH) models with Johnson's S_U distribution (JSU) and Pearson Type IV distribution (PSIV) provide a better fit, while for SS3, which is more volatile and shorter in duration, both EGARCH and generalised autroregressive score (GAS) models perform well with skewed student's t-distribution (SST), skewed generalised error distribution (SGED). The estimation of Group Transfer Entropy breaks the myth that Bitcoin generates risk spillovers to other currencies.

Detection of changepoints based on ICA demonstrates competitive and even better performance sometimes when compared with the proposed t-SNE based procedure. The computation time taken by ICA is very less. Though t-SNE based method worked better for smaller samples sometimes, both the proposed methods are competitive. We verify our claims by extensive simulation and application on real datasets. We apply the ICA based technique of changepoint estimation on several multistock portfolio and it rightly detects the position of changepoints which coincides with the recession of 2008. The information flow is also observed to traverse from the west to east.