

Chapter 6

Extremal Index Estimation: Application to Financial Data

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ABSTRACT

In finance it is crucial to understand the risk of occurrence of extreme events such as currency crises or stock market crashes. It is important to model the distribution of extreme events. Extreme value theory is known to accurately estimate quantiles and tail probabilities of financial asset returns. These kinds of data are usual related to heavy tailed distributions, where a relevant parameter is the tail index. Fitting data to heavy tail distributions usually assumes independent observations. However, the most usual real market scenario describes clusters of extreme events rather than isolated records over some period of time. In that case, estimating tail probabilities includes estimating the extremal index. This chapter describes the usual extremal index estimators based in different approaches and illustrates their values for a real financial data set. Computations are provided by the use of suitable R packages.

INTRODUCTION

Financial institutions need to know appropriate models for predicting market evolution. They must be prepared for all possible outcomes. If there is a crash in stock market it is vital to have an adequate notion of the magnitude of the consequences. Managing a portfolio involves measuring risk, associated to the ability to overcome some low values that might occur. Central banks need to provide safety limits to protect bank clients from a catastrophic event with a fund reserve. Banks need to develop tools that provide early warning indicators of periods of crisis.

Extreme Value Theory (EVT) models the occurrence of rare events such as high (low) values of stock market or other kind of asset returns over some period of time. In financial markets there is a special interest related to the behaviour of maximum (minimum) values as they might represent a big difference to the owner's assets value. These kind of values occur in different ways, being observed either with an isolated frequency or, as it happens most of the times, in clusters of high (low) values. They may also occur in periods of low volatility and others of greater fluctuation. The extreme value distribution is

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thus one of the most important issues to study for assuring a good perspective of the market evolution. The study of the limiting distribution for a long period a time offers a different knowledge of the tail model. When clusters of extreme values are present, this limiting distribution is affected by an extra parameter, the so-called extremal index. This index is somehow related to the dependence structure of the sequence of observed values and measures, in some way, the magnitude of the periods in which extreme values occur.

In this chapter, extreme value theory is revisited, beginning with a review of the main concepts when dealing with independent and identically distributed (i.i.d.) samples. In this case the limiting distributions of the maxima, under suitable transformations comes from the well-known theorem of Fisher-Tippet (Fisher & Tippet, 1928).

For some particular sequences that verify suitable conditions related to its dependence structure, it is also possible to obtain the limiting maximum distribution which depends on the extremal index. The second part of the chapter summarizes the required conditions for studying the extremal index and its most popular estimators are presented. Most of the recent estimator proposals that are included are based on different approaches. The chapter concludes with an application to real data, beginning with an exploratory analysis and then the estimation process. This illustration example is supported with special designed available R-packages (R Core Team, 2015) and also presents the applied R-code so the reader can replicate by himself the obtained results.

Extreme Value Theory

EVT is particularly useful in finance namely, to estimate probabilities of extreme events. For example, if $\{R_n\}_{n \geq 1}$ is a sequence of random variables representing some stock returns over some period of time, it is crucial to have proper estimates of the (usual) small probabilities of overcome some high (low) value. Extremes refer to the maximum or minimum value of such a sequence. If some “safety” threshold is known, the probability of the minimum of a sequence of stock returns being bellow that threshold means that there is a probability of falling into dangerous limits.

Although studies related to EVT begun in the 1920s with Boortkiewicz, Fréchet, Von Mises and Tippet (Gumbel, 2004), (Beirlant, Caeiro, & Gomes, 2012) and received some attention later (Gnedenko, 1943), it is only in the 1950s that a serious development takes place. This “lift off” of the EVT research is associated with a catastrophic event of floods in the Netherlands in the 1st of February of 1953, originated by a great storm in the North Sea: 1850 died because of the failure of several dykes that didn’t stood up facing the strength of the waters (Woo, 1999). To avoid a similar disaster, the Dutch government made some investments: a commission was nominated with the purpose of performing an econometric analysis, in order to establish an optimal safety level to build robust higher dykes. The research to find solutions to solve this kind of problems was therefore intensified by the mathematicians and names like Laurens De Haan have given big contributions towards the state of knowledge that EVT has nowadays (David & Edwards, 2001), (Fraga Alves, Gomes, & De Hann, 2003) (Gomes & Guillou, 2015).

There are two distinct ways of covering the study of extreme observations. One way is the so called “Block Maxima” approach that implicates the study of the distribution of maximum values identified over some disjoint set of blocks. The other way, known as “Peaks Over Threshold” (POT) method, consists of defining some upper threshold and then analyse the excesses above that threshold. The first results on fitting the Generalized Extreme Value (GEV) distribution and verify the necessary assumptions. The

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