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Managing extreme risk in some major stock markets: An extreme value approach

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ABSTRACT

The study investigates the relative performance of Value-at-Risk (VaR) models using daily share price index data from six different countries across Asia, Europe and the United States for a period of 10 years from January 01, 2000 to December 31, 2009. The main emphasis of the study has been given to Extreme Value Theory (EVT) and to evaluate how well Conditional EVT model performs in modeling tails of distributions and in estimating and forecasting VaR measures. We have followed McNeil and Frey's (2000) two stage approach called Conditional EVT to estimate dynamic VaR. In stage 1, we model the conditional volatility of each series using an appropriate asymmetric GARCH model which serves to filter the return series such that the asymmetric GARCH residuals are closer to iid than the raw return series. In stage 2, we apply EVT to model the fat tails of the asymmetric GARCH residuals. We have compared the accuracy of Conditional EVT approach to VaR estimation with other competing models. The best performing model is found to be the Conditional EVT for the entire sample. To confirm whether the Conditional EVT would still be the best for a sub-period, we have compared the forecasting accuracy for the sub-sample of bull market. Here too the Conditional EVT maintains its superiority even more precisely. Since the Conditional EVT approach clearly dominates other competing models in terms of VaR forecasting, we would advocate the use of the model when managing tail related market risk in such equity markets.

1. Introduction

In the last two decades, Value-at-Risk (VaR) has become a very popular risk management tool in many different types of organizations. A VaR model measures market risk by determining how much the value of a portfolio could decline with α% probability over a certain time horizon τ as a result of changes in market prices or rates. If for example, $\alpha = 1\%$ and τ is one day, the VaR measure would be an estimate of the decline in the portfolio value that could occur with 1% probability over the next trading day. In other words, if the VaR measure is accurate, losses greater than the VaR measure should occur less than 1% of the time.

The most commonly used VaR models assume that the probability distribution of the daily financial asset return is normal, an assumption that is far from reality. Many of the asset returns exhibit significant amounts of excess kurtosis. This means that the probability distributions of these daily returns have "fat tails" so that extreme outcomes happen much more frequently than that would be predicted by the normal distribution assumption. In this article, we show how the normal distribution assumption can be relaxed. We propose an extreme value approach popularly known as Extreme Value Theory (EVT) to calculate VaR that allows the user to choose more generalized fat tailed distributions for the daily stock market returns.

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The EVT focuses on modeling the tail behavior of a profit/loss distribution using only extreme values rather than the whole sample. In addition, EVT offers a parametric estimate of a tail distribution. Focusing only on extreme returns EVT yields a more precise estimate for the VaR, since by definition VaR measures the economic impact of rare events. Hence EVT, which is a statistical theory of extremes, appears to be a more natural and robust approach to tail related extreme risk measurement.

The EVT has been around for some time, from the pioneering work on block maxima of Fisher and Tippett (1928) and Gnedenko (1943) to the exposé by Gumbel (1958). More recently, Balkema and de Haan (1974) and Pickands (1975) have used threshold-based extreme value methods. Since then the theory has been applied in different areas over the years, for instance, in hydrology and wind engineering, and lately we have seen its application in finance and insurance. Presentation emphasizing these applications can be seen in Embrecths, Kluppelberg, and Mikosh (1997) and in Reiss and Thomas (2007).

By now EVT has already found numerous applications for VaR estimation on financial markets. Longin (1996) examines extreme movements in U.S. stock prices and shows that the extreme returns obey a Frechet fat-tailed distribution. Ho, Burridge, Cadle, and Theobald (2000) and Gencay and Selcuk (2004) apply EVT to emerging stock markets which have been affected by financial crisis. They report that EVT dominates other parametric models in forecasting VaR, especially for more extreme tail quantiles. Gencay, Selcuk, and Ulugulyagci (2003) reach similar conclusions for the Istanbul Stock Exchanges Index (ISE-100). Muller, Dacorogna, and Pictet (1998) and Pictet, Dacorogna, and Muller (1998) compare the EVT method with time-varying GARCH model for foreign exchange rates. Bali (2003) adopts the EVT approach to derive VaR for U.S. Treasury yield changes. Ren and Giles (2010) present an application of EVT to daily returns of crude oil prices in the Canadian spot market between 1998 and 2006. Dimitrakopoulos, Kavussanos, and Spyros (2010) evaluate the forecasting accuracy of a variety of popular VaR approaches for 16 emerging and 4 developed equity markets and find that the EVT model provides the best backtesting results. Mutu, Balogh, and Moldovan (2011) analyze the performance of different VaR models using daily market indices of Central and Eastern European stock markets. They observe that only advanced VaR models such as EVT or GARCH models can adequately measure the market risk. Kittiakarasakun and Tse (2011) compare EVT based VaRs with GARCH based VaRs using data from Asian stock markets. They, however, observe that the dynamic GARCH type models which allow for time varying volatility, provide better VaR performance than do the static EVT models.

In all these papers while applying EVT to forecast VaR the focus is on estimating the unconditional (stationary) distribution of asset returns. The researchers ignore the stochastic volatility exhibited by most financial return series. Hence, none of the previous EVT-based methods for quantile estimation yields VaR estimates which reflect the current volatility background. Moreover, the use of EVT relies on an important assumption of independent and identically distributed (iid) observations, which obviously does not match the actual situation of financial return series. In order to overcome the drawbacks the immediate solution is provided by McNeil and Frey (2000). Using a two stage approach, McNeil and Frey estimate a GARCH model in stage one with a view to filtering the return series to obtain (nearly) iid residuals. In stage two, the EVT framework is applied to the standardized residuals. The advantage of this GARCH–EVT combination lies in its ability to capture conditional heteroscedasticity in the data through the GARCH framework, while at the same time modeling the extreme tail behavior through the EVT method.

Following McNeil and Frey (2000), Bali and Neftci (2003) apply the GARCH–EVT model to U.S. short-term interest rates and show that the model yields more accurate estimates of VaR than that obtained from a Student t-distributed GARCH model. Fernandez (2005) and Bystrom (2004) also find that the GARCH–EVT model performs better than the parametric models in forecasting VaR for various international stock markets. In an energy application, Bystrom (2005) employs GARCH–EVT framework to NordPool hourly returns. He finds that the extreme GARCH-filtered residuals obey a Frechet distribution. Furthermore, the GARCH–EVT model produces more accurate estimate tails than a pure GARCH model. Recently, many researchers such as Cotter (2007), Ghorbel and Trabelsi (2008) and Marimoutou, Raggad, and Trabesi (2009) use GARCH–EVT model to measure VaR in different markets and find that the model predicts better estimates of VaR than that of other well-known modeling techniques.

In this paper we compute VaR for 3 emerging and 3 developed stock markets across Asia, Europe and the United States. A plethora of VaR models are examined. However, the primary focus of this paper is to compare the accuracy of GARCH–EVT approach for VaR calculation with other competing approaches. We have followed McNeil and Frey's (2000) two stage approach and demonstrated in detail how the approach combines the simple EVT approach with the appropriate asymmetric GARCH model to accommodate both asymmetric conditional volatility and fat tailed return distribution to estimate the tail related risk measures in some emerging as well as developed stock markets of the world.

Although both the negative and the positive tails of stock return distributions are interesting from a risk management perspective, most studies of extreme stock returns focus on losses (as opposed to gains), and large crashes are generally considered more important than large booms. In this paper, we look at six countries' aggregate stock markets and we expect losses to be of more general interest than gains. To save space, we therefore chose to focus solely on the negative tails of the distribution of the six return series.

The remainder of the paper is structured as follows. Section 2 presents a brief overview of EVT, describes the estimation of VaR and then explains McNeil and Frey's (2000) two stage approach called Conditional EVT to estimate dynamic VaR. Section 3 documents the data used in the study. Section 4 presents the empirical findings from both in-sample and out-of sample evaluations of VaR measures. Finally, Section 5 concludes the study.

2. Modeling the tails of stock return distributions

In the following subsections, we present an overview of the theoretical framework of EVT, describe VaR and explain how conditional EVT is applied to VaR.