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Asymmetry in tail dependence in equity portfolios☆

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HIGHLIGHTS

- The tail dependence between US equity portfolios and the US market is asymmetric.
- We describe a multivariate t distribution with asymmetry in the lower and upper tail dependence.
- The lower and upper tail dependence parameters are estimated by maximum likelihood.
- The estimated tail dependence parameters are consistent with the data provided volatilities and correlations are allowed to vary over time.

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ABSTRACT

The asymmetry in the tail dependence between U.S. equity portfolios and the aggregate U.S. market is a well-established property. Given the limited number of observations in the tails of a joint distribution, standard non-parametric measures of tail dependence have poor finite-sample properties and generally reject the asymmetry in the tail dependence. A parametric model, based on a multivariate noncentral *t* distribution, is developed to measure and test asymmetry in tail dependence. This model allows different levels of tail dependence to be estimated depending on the distribution's parameters and accommodates situations in which the volatilities or the correlations across returns are time varying. For most of the size, book-to-market, and momentum portfolios, the tail dependence with the market portfolio is significantly higher on the downside than on the upside.

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1. Introduction

Several recent papers have pointed out that the dependence across asset returns may be stronger in bearish markets than in bullish markets. Longin and Solnik (2001) investigate the asymmetry of the correlation across markets using the exceedance correlation, i.e., the correlation between realizations that are jointly above or below a given threshold. For international stock markets, they demonstrate that the correlation between large negative returns does not converge to zero, but instead, tends to increase with the threshold. At the same time, the correlation between large positive returns decreases to zero. Ang and Bekaert (2002) describe the joint behavior of market returns using a regime-switching model and provide empirical evidence that cross-market correlation is significantly higher over bearish markets than over bullish markets. Ang and Chen (2002) formally test the asymmetry in the dependence across stock returns using exceedance correlations. They demonstrate that the correlation between Fama–French portfolio returns and the market return is significantly larger when the market return is negative than when it is positive. They also show that this correlation asymmetry is greater for

☆ A Technical Appendix is available on the website of the author.

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small firms, value firms, and past losers. Hong et al. (2007) also investigate the asymmetric dependence between portfolio returns and the market return. They find that this asymmetry matters for asset allocation for investors with disappointment-aversion preferences.

All of the above-mentioned papers provide empirical evidence that stock returns display asymmetric dependence in bearish and bullish markets. This evidence raises several interesting questions. First, it is not clear whether the asymmetric dependence reported in these papers really implies an asymmetric dependence in the tails of the distribution, as initially claimed by Longin and Solnik (2001). It may well be that dependence vanishes once one considers extreme realizations, as is typical with Gaussian-type distributions. Tail dependence is a key measure for risk management, which mainly focuses on the extreme events of joint distribution. The present paper contributes to this literature by investigating the tail dependence between the Fama–French portfolio returns and the market return. Specifically, we show that the tail dependence is indeed, very often asymmetric, i.e., joint extreme negative returns are more likely to occur than joint extreme positive returns.

Another question raised by the recent literature relies on the difficulty of finding an appropriate model for testing the asymmetry in the tail dependence. Ang and Chen (2002) find that none of the standard models that they investigate is able to generate the asymmetric pattern observed in the data. Hong et al. (2007) use an ad-hoc mixed copula model to reproduce the empirical asymmetry found in tail dependence. Most of the multivariate distributions used for modeling financial returns are unable to produce reliable estimates of the left-tail and right-tail dependence found in the actual joint distribution. For instance, the asymmetric t distribution (Mencia and Sentana, 2009; Hu and Kercheval, 2010) implies full dependence on one side of the distribution and full independence on the other side. By contrast, the skewed t distribution (Jondeau and Rockinger, 2009) captures the asymmetry in the exceedance correlations but does not generate asymmetric tail dependence. Similarly, most of the copulas considered in the empirical literature generate tail dependence for the extremes on one side of the distribution, but no dependence for the extremes on the other side (see, among others, Lee and Long, 2009). None of these models allows a free measure of the asymmetry in the tail dependence. Last, a few papers have investigated the asymmetry in tail dependence from a non-parametric standpoint, in the context of extreme value theory (Longin and Solnik, 2001; Poon et al., 2004). As it is illustrated below, one difficulty with this approach is that the non-parametric estimators typically have poor finite-sample properties.

This paper proposes a distribution that allows a different level of tail dependence for each side of the distribution so that one can directly test the asymmetry in the tail dependence. This distribution, namely the non-central t distribution (NCT), was initially introduced by Kshirsagar (1961) in a different context. The aim of this paper, then, is to describe how to use the NCT distribution to model and test the asymmetry in the distribution's tails in a conditional setup. The NCT distribution has a natural interpretation in terms of a normal mixture distribution. As a consequence, it shares their properties: in particular, it is closed under contemporaneous aggregation. Another important issue in a multivariate context is the fact that the tail dependence may be different from a pair of variables to another. In the copula literature, this issue has been recently addressed through vine copulas (Nikoloulopoulos et al., 2012) and hierarchical Archimedean copulas (Okhrin et al., 2013). Although the NCT also allows the tail dependence to be different from one pair to another, we do not focus on this property in this paper.

The approach developed in this paper is a parametric one. The objective is to provide a full description of the joint distribution of the time series. The key properties of the tails are then deduced from this distribution so that the test of symmetry in the tail dependence is based on the restrictions on the model's parameters. It should also be noted that, given its analytical expression, the NCT distribution provides a quick estimation of both the model's parameters and of the distribution's quantiles.

We investigate the dependence between size, book-to-market, and momentum portfolios and the market index, following Ang and Chen (2002) and Hong et al. (2007). The NCT provides a good description of the data and is able to reproduce fairly well the observed asymmetric tail dependence, provided that returns are filtered for AR and GARCH effects. The structure of the paper is as follows. Section 2 describes the data and provides empirical evidence of asymmetry in the tail dependence using non-parametric statistics. Section 3 describes the NCT and its main properties and discusses the estimation procedure used in the paper. Section 4 describes estimates of the model and demonstrates that the NCT provides a good fit of the data, including the ability to reproduce the asymmetry in the tail dependence. Section 5 concludes.

2. Empirical evidence of tail asymmetry

2.1. Data

As in most of the papers discussed in the introduction, the analysis is based on the US equity market. Ang and Chen (2002) and Hong et al. (2007) already considered several Fama–French portfolios, which were sorted based on size, book-to-market ratio, momentum, or industry. From these studies, it is known that the relation between size or momentum portfolios and the market index is highly asymmetric but less so for the book-to-market sort. In the following, we consider size, book-to-market, and momentum portfolios. For size portfolios, all common stocks listed on NYSE, AMEX, and NASDAQ of companies incorporated in the US are sorted by market capitalization. Then, five quintile portfolios are constructed and the daily return of a given portfolio is computed as the value-weighted average of the daily simple returns of the constituting stocks. For book-to-market portfolios, all common stocks are sorted by book equity to market equity ratio. The five quintile portfolios are constructed and the daily return is computed in the same way. For momentum portfolios, all common stocks are sorted by cumulative returns from 12 to 2 months prior to portfolio formation. Ten decile portfolios are then constructed.

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