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Long-term asset tail risks in developed and emerging markets

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ABSTRACT

A power law typically governs the tail decay of financial returns but the constancy of the so-called tail index which dictates the tail decay remains relatively unexplored. We study the finite sample properties of some recently proposed endogenous tests for structural change in the tail index. Given that the finite sample critical values strongly depend on the tail parameters of the return distribution we propose a bootstrap-based version of the structural change test. Our empirical application spans developed and emerging financial asset returns. Somewhat surprisingly, emerging stock market tails are not more inclined to structural change than their developed counterparts. Emerging currency tails, on the contrary, do exhibit structural shifts in contrast to developed currencies. Our results suggest that extreme value theory (EVT) applications in hedging tail risks can assume stationary tail behavior over long time spans provided one considers portfolios that solely consist of stocks or bonds.

1. Introduction

The 1997 Asian crisis, the LTCM debacle or the recent subprime credit crunch have increased the awareness of both academics and practitioners on the importance of accurately assessing the likelihoods of so-called extreme events. Stated otherwise, fluctuations in financial markets whose occurrence is relatively rare can drive banks or institutional investors into overnight financial distress when they strike. However, the academic interest into large tail events is far from new (for an early reference see e.g. Mandelbrot, 1963). He was one of the first to acknowledge that overnight financial market turbulence cannot be captured by the normal distribution function (df). More specifically, tail probabilities show a polynomial tail decay ("heavy" tails) in contrast to the exponential tail decays of so-called "thin tailed" models like the normal df and most financial asset classes exhibit this "heavy tail" characteristic. Numerous empirical studies focus on identifying the degree of probability mass in the tail by estimating the so-called tail index α.[1] The integer part of this parameter reflects the number of bounded statistical moments of the corresponding unconditional df.

The causes and consequences of changes in the tail index (provided changes occur) remain relatively unexplored. Conditional volatility models like the GARCH-type class reconcile a stationary unconditional df (constant tail index) with clusters of high and low volatility in the conditional df. However, the question arises whether it is realistic to assume that the tail of the unconditional df (and thus measures of long-term risk like unconditional quantiles) remains invariant over long time periods. In other words: can highly volatile periods like the 2007–2010 financial turmoil and periods of market quiescence both be explained by a single unconditional df? Potential causes of tail index changes include structural shifts like e.g. changing trading systems, financial regulatory reform and financial liberalization or changes in the political environment. Moreover, economists seem to agree that these structural changes are more frequently happening in emerging economies. Our empirical application therefore distinguishes between developed and emerging return tails in order to evaluate whether emerging return tails are relatively more prone to structural shifts in the tail index.

Testing for structural change in the tail behavior of the unconditional distribution is relevant from both a statistical and economic perspective. First, whether extreme value theory (EVT) or e.g. the cited GARCH models are applicable depends on the stationarity assumption for the unconditional tail. Also, a

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[1] Jansen and de Vries (1991), Longin (1996) and Hartmann et al. (2004) investigate the probability mass in the tails of stock market returns; whereas Koedijk et al. (1990, 1992), Hols and de Vries (1991) and Hartmann et al. (2003) consider fat tails in foreign exchange rate returns. Bond extremes remain relatively unexplored except for de Haan et al. (1994) and Hartmann et al. (2004).

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non-constant tail index implies a violation of covariance stationarity which complicates standard statistical inference based on regression analysis. From an economic perspective, quantifying the correct level of the tail index is relevant for risk managers as it constitutes a necessary ingredient for calculating the unconditional Value-at-Risk (VaR) very far into the distributional tail, i.e. so-called "tail risk". Indeed, whereas regulatory instances require the financial industry to report and backtest 5% and 1% VaR, these events hardly represent extreme events that can trigger financial companies into overnight financial distress. Instead, evaluating downside risk much further into the tail represents useful additional information to e.g. traditional stress testing approaches. Other EVT applications in portfolio selection and risk management include safety first portfolio selection for pension funds (Jansen et al., 2000) or the assessment of trading limits for unhedged forex positions in commercial banks (see Danielsson and de Vries, 1997). If one incorrectly assesses the actual tail index value in these exercises due to e.g. the presence of structural breaks, unconditional VaR quantiles are most probably biased which erodes the effectiveness of financial risk management and the proper monitoring of overall financial stability (e.g. wrong allocation of risky investments in pension fund portfolios, wrong trading limits for forex traders within banks, etc.).

The scant empirical literature on the constancy issue mainly focuses on testing for a single known (i.e. exogenously selected) breakpoint in the tail index.[2] To the best of our knowledge, Quintos et al. (2001) constitutes the only stability study on detecting (single) breakpoints as well as corresponding break dates in the tail index.[3] Our study extends and refines the previous breakpoint analyses in several directions. First, we select the number of extreme returns to estimate the tail index by minimizing its Asymptotic Mean Squared Error (AMSE) instead of conditioning on a fixed fraction of the total sample. The former approach constitutes common practice in EVT whereas taking a fixed percentage of extremes leads to a degenerate asymptotic limiting df for the tail index estimator and accompanying stability tests. Second, our simulation study of the stability tests' finite sample properties is much more general than previous studies because we also use data generating processes (DGP's) that consider higher order tail behavior or empirical stylized facts like e.g. volatility clustering in returns. Last but not least, we apply stability tests to a large cross section of assets and asset classes whereas previous studies typically only focus on a limited number of assets within the same asset class. We also distinguish between developed market financial assets and emerging market financial assets in order to judge whether the latter are more prone to shifts in the tail behavior.

Anticipating our results, we find that size, (size-corrected) power and the ability to detect breaks in finite samples vary considerably with the assumed DGP. That is the reason why we propose to bootstrap the critical values in empirical applications for each data set separately. Moreover, the outcomes of our experiments on size-corrected power and the ability to detect breaks suggest that a "recursive" version of the stability test is to be preferred provided the sample is sufficiently large (at least 2000 observations). Upon applying a bootstrap-based version of this test to a large cross section of assets and asset classes, we mainly detect breaks in the tail behavior of emerging currencies.

The rest of the paper is organized as follows. Section 2 provides a refresher on the statistical theory of heavy tails and accompanying endogenous stability tests. Section 3 contains an elaborate Monte Carlo investigation of the endogenous breakpoint tests' size, power and break date ability. Section 4 provides an extensive empirical investigation on the tail stability of a variety of developed and emerging asset tails. Section 5 contains concluding remarks.

2. Testing structural change in tail behavior: theory

We provide a short digression on the theory and estimation of the tail index α followed by a discussion of some temporal stability tests for this parameter. We start from the empirical stylized fact that sharp fluctuations in financial market prices exhibit fat tails, see e.g. Mandelbrot (1963) for an early reference or the more recent monograph by Embrechts et al. (1997). Without loss of generality, we express estimation and testing procedures in terms of the right tail, i.e. the survivor function $P\{X \geqslant x\} := 1 - F(x)$. Our empirical investigation focuses on sharp drops in the prices of risky securities. This requires taking the negative of a return series prior to applying the sketched framework. Under fairly general conditions, we can approximate the survivor function of heavy tailed (or "regularly varying") distributions by the second order Taylor expansion for large x:

$$1 - F(x) = ax^{-\alpha}(1 + bx^{-\beta} + o(x^{-\beta})), \tag{1}$$

with $a > 0,\ \alpha > 0,\ b \in \Re,\ \beta > 0$, see e.g. de Haan and Stadtmüller (1996). The parameters β and b that govern the second order behavior in (1) reflect the deviation from pure Pareto behavior in the tail. Notice that if we talk about the "second order parameter" of a fat tailed or regularly varying process later on in the paper, we always refer to the ratio $\rho = -\beta/\alpha$. The case $\beta = \rho = 0$ corresponds to the expansion $P\{X \geqslant x\} \approx ax^{-\alpha}[1 + b\ln x]$. The tail specializes to an exact Pareto when $b = 0$.

The regular variation property implies that the (appropriately scaled) upper extremal returns lie in the maximum domain of attraction of the Type-II extreme value ("Frechet") distribution. The tail index α reflects the speed at which the tail probability in (1) decays if x is increased. A lower tail index implies a slower probability decay and higher probability mass in the tail of X, *ceteris paribus* the level of x. The regular variation property, *inter alia*, implies that distributional moments $E(X^r)$ with $r > \alpha$, are unbounded, signifying "fat tails". Regularly varying probability distributions include the Student-*t*, symmetric stable, Burr, and Frechet df as well as the GARCH class of conditional volatility models.[4] As for the tail of the standard normal distribution, a popular tail approximation expresses the survivor function $1 - \Phi(\cdot)$ in terms of the density $\phi(x)$:

$$1 - \Phi(x) \approx \frac{\phi(x)}{x}, \quad x \quad \text{large} = (2\pi x)^{-1} \exp\left(-\frac{1}{2}x^2\right),$$

which clearly describes an exponentially declining tail, see Feller (1971a, p. 175). We classify distributions with this type of tail decay as "thin tailed" because the tail probability $1 - \Phi(x)$ declines much

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[2] The breakpoint literature includes Koedijk et al. (1990, 1992), Jansen and de Vries (1991), Pagan and Schwert (1990) and Straetmans et al. (2008). One can distinguish tests for structural change in the tail index from cross sectional equality tests (see e.g. Koedijk et al., 1990, on exchange rates or Jondeau and Rockinger, 2003, on stock markets) or asymmetry tests between left and right tails of the same series (see e.g.

[3] Werner and Upper (2002), Galbraith and Zernov (2004) and Candelon and Straetmans (2006) already apply the Quintos et al. (2001) methodology to test for tail stability in bund Future returns, US stock market returns and Asian currency returns, respectively. However, they all use the Quintos et al. (2001) asymptotic critical values. We argue in this paper that these critical values do not take into account the bias in the Hill estimator for the tail index and lead to overrejection of the null hypothesis of tail index constancy.

[4] Hall (1982) imposes the more stringent condition $\alpha = \beta$ on the tail expansion. This covers certain distributions like the stable laws and the type II extreme value distribution (Frechet); but it does not apply to e.g. the Student-*t* or the Burr df. For the Student-*t* df the tail expansion (1) holds, though, with α equal to the degrees of freedom parameter and $\beta = 2$. As for the Burr df, the 2nd order parameter can be freely chosen. The value of β is unknown for the GARCH class.