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Emerging markets and heavy tails

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A B S T R A C T

Emerging countries are held to be subject to more frequent and more pronounced external and internal shocks than their developed counter-parts. This suggests that key variables pertaining to their markets, including their exchange rates, will be marked by greater likelihood of extreme observations and large fluctuations. We focus on the hypothesis that compared to developed country exchange rates, emerging country exchange rates will be more pronouncedly heavy-tailed. We find support for the hypothesis using recently proposed robust tail index estimation methods which, in particular, perform well under heavy-tailed dependent GARCH processes that are often used for modeling exchange rates. According to the estimation results reported in the paper, variances may be infinite for several emerging country exchange rates. Tail index values $\zeta = p \in (2.6, 2.8)$ appear to be at the dividing boundary between the two sets of countries: while the moments of order $p \in (2.6, 2.8)$ are finite for most of the developed country exchange rates, they may be (or are) infinite for most of the emerging country exchange rates. We also study the impact of the on-going financial and economic crisis, and find that heavy-tailedness properties of most exchange rates did not change significantly with the onset of the crisis. At the same time, some foreign exchange markets have experienced structural changes in their heavy-tailedness properties during the crisis.

1. Introduction

1.1. Heavy tails in economics and finance

Foreign exchange markets are arguably the world's largest markets, operating continuously, and bringing together a wide variety of buyers and sellers, within and across national borders. In recent years these markets have been characterized by turbulence and volatility, with extreme variations marking some exchange rates. As the literature on the determination of exchange rates points out, there are many processes capable of generating extreme exchange rate variations. These include economic crises, speculative attacks, bailouts, stabilization efforts, regime reforms and regulatory changes, among others. Recent theoretical literature contains useful models that explain extreme changes in financial returns, in terms of trading actions of large market participants (see, for instance, Gabaix et al., 2006), and in terms of government interventions in the case of foreign exchange markets.

Large fluctuations in exchange rates carry significant real consequences for international trade, foreign investment, asset prices, and a wide range of other economic and financial outcome variables. The on-going financial and economic crisis has raised the need for accurate estimates of probabilities associated with large changes in financial returns and exchange rates. Emerging and developing countries are generally held to be subject to more frequent and more pronounced external and internal shocks than their developed counter-parts, and in that context it is ever more important to identify currencies that are relatively more prone to large fluctuations.

Numerous contributions in economics, finance, risk management and insurance have concluded that distributions of many variables of interest deviate from the Normal distribution paradigm, particularly in terms of heavy tails. For example, it is virtually impossible for Gaussian distributions to generate variations of the order of magnitude observed on Black Monday in 1987, according to the striking illustrations in Ch. 2 in Stock and Watson (2006). Detailed discussion and reviews are available in Embrechts et al. (1997), Cont (2001), Rachev et al. (2005), Gabaix (2009), Ibragimov and Walden (2007), Ibragimov (2009a), and references

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therein. This stream of literature goes back to Mandelbrot (1963) who pioneered the study of heavy-tailed distributions in economics and finance (see also Fama, 1965, and the papers in Mandelbrot (1997)).

The potential for large changes in random variables is characterized by the probability mass in the tails of their distributions. In models involving a heavy-tailed risk, return or foreign exchange rate, the variable of interest r is usually assumed to have a distribution with power tails, such that:

$$P(r > x) \sim \frac{C_1}{x^{\zeta_1}}, \tag{1}$$

$$P(r < -x) \sim \frac{C_2}{x^{\zeta_2}}, \tag{2}$$

$\zeta_1, \zeta_2 > 0$, $C_1, C_2 > 0$, as $x \to +\infty$, that implies, with $\zeta = \min(\zeta_1, \zeta_2)$,

$$P(|r| > x) \sim \frac{C}{x^{\zeta}}, \tag{3}$$

$C > 0$, as $x \to +\infty$ (here and throughout the paper, $f(x) \sim g(x)$ as $x \to +\infty$ means that $\lim_{x\to+\infty} \frac{f(x)}{g(x)} = 1$). The parameters ζ, ζ_1 and ζ_2 in (3) and (1), (2) are referred to, respectively, as the tail index (or the tail exponent), the right tail index and the left tail index of the distribution of r. These indices characterize the heaviness (the rate of decay) of the tails of power law distributions (1)–(3). The greater the probability mass in the tails, the smaller the tail index parameters, and vice versa. Thus smaller values of ζ correspond to larger likelihood of outliers in realizations of the variable.

The models (1)–(3) allow one to determine the quantiles of variable r that correspond to small tail probability levels, and the corresponding loss exceedance probabilities and risk measures including the value at risk (VaR) and the expected shortfall. Differences between markets in their tail index estimates point to differences in risk that they carry. The heavy-tailedness property is of key interest to risk managers, financial regulators, financial stability analysts and policy makers concerned with the likelihood of extreme values in financial and exchange rate returns.

Tail indices ζ characterize the maximal order of finite moments of the variable r considered, as discussed in Appendix. In particular, the fourth moments and thus the kurtosis of the variable are finite if and only if $\zeta > 4$; the variances of r are finite if and only if $\zeta > 2$; and the means of r are finite if and only if $\zeta > 1$. The tail index can be regarded as being infinite for normal distributions where the decay to zero of distributional tails in (1)–(3) is faster than exponential, and thus the moments of an arbitrary order are finite. Many recent studies have found that in developed market economies, tail indices in the heavy-tailed model (3) for financial returns and exchange rates typically lie in the interval $\zeta \in (2,5)$ (see, among others, Loretan and Phillips, 1994; Gabaix et al., 2006; Ibragimov and Walden, 2007; Gabaix, 2009; Ibragimov, 2009a, and references therein). The estimates $\zeta \in (2,4)$ imply that the return variables have finite variances and finite first moments; however, their fourth moments are infinite.

Finiteness of first moments is of key importance for the optimality of diversification in the value at risk framework and for the robustness of a number of economic models for the variable of interest (see Ibragimov and Walden, 2007; Ibragimov, 2009a; Ibragimov et al., 2009). The finiteness of variances is crucial for the applicability of classical statistical and econometric approaches, including regression and least squares methods, to economic and financial variables of interest. The problem of potentially infinite fourth moments of economic and financial time series needs to be taken into account when analysing them using autocorrelation-based methods and related inference procedures (see, among others, the discussion in Granger and Orr (1972), and in a number of more recent studies, e.g., Ch. 7 in Embrechts et al. (1997), Cont (2001), and references therein).

1.2. Robust inference for heavy-tailed exchange rates: emerging vs. developed countries

Our principal goal in this paper is the robust analysis of heavy-tailedness properties of exchange rates of emerging and developing countries, in comparison with developed countries. This comparative examination is motivated by the generally held view that the former set of countries are more subject to severe external and internal shocks, and therefore suffer greater potential for extreme changes in financial returns and exchange rates. We use recently proposed robust tail index estimation methods, based on log–log rank-size regressions with optimal shifts in ranks, and correct standard errors (see Gabaix and Ibragimov, 2011, and Appendix), applying them to large data sets on daily exchange rates for a number of countries. This is in contrast to earlier studies of exchange rates of emerging countries which have tended to use model-specific parametric maximum likelihood procedures or (semiparametric) Hill's estimators, with a number of contributions using relatively small data sets, with potentially non-robust conclusions (see the discussion in Appendix).[3,4] We also report results of an analysis of asymmetry in extreme upward, as against downward changes in the exchange rates considered.

A further dimension to our analysis is the on-going economic crisis. We assess whether the crisis led to significant changes in the likelihood of large variations in exchange rates. We also draw conclusions on the applicability of standard economic and econometric models, including regression methods, and models explaining heavy tails in financial markets.

We find that the tail indices for exchange rates of emerging countries are indeed considerably smaller than those of developed countries. Our estimates imply that, in contrast to developed countries, the value of the tail index $\zeta = 2$ is not rejected at commonly used statistical significance levels for the exchange rates of several emerging countries (Section 3), implying that their variances may be infinite. Tail index values $\zeta = p \in (2.6, 2.8)$ appear to be at the dividing boundary between developed country exchange rates on the one hand, and emerging country exchange rates on the other: while the moments of order $p \in (2.6, 2.8)$ are finite for most of the developed country exchange rates, they may be (or are) infinite for most of the emerging country exchange rates.

With respect to the on-going financial and economic crisis, we find that while the heavy-tailedness properties of most exchange rates did not change significantly, a few foreign exchange markets did see structural changes. There was significant increase in the degree of heavy-tailedness of the Swiss franc and pound sterling, and surprisingly, a decrease in the degree of heavy-tailedness of the Russian rouble.

These results have a number of implications. They underscore the need for robust econometric and statistical methods in the analysis of emerging country financial markets (see the discussion in Sections 1.1 and 4). They highlight aspects of macroeconomic management and policy in emerging countries. In a structural

[3] Robustness of the tail index estimation approaches based on log–log rank-size regressions is illustrated by their favorable performance under deviations from power laws (1)–(3) in the form of slowly varying factors and dependent GARCH processes that are often used for modeling financial returns, exchange rates and other economics and financial time series (see Gabaix and Ibragimov, 2011, and the discussion in Appendix).

[4] For illustration, we compare the tail index estimates obtained using the log–log rank-size regression approach with those obtained using Hill's estimation procedure used in previous works in the literature (see Section 3). The comparisons typically lead to similar conclusions for both estimation approaches.