Journal of Empirical Finance 17 (2010) 241–254

Contents lists available at ScienceDirect

Journal of Empirical Finance

journal homepage: www.elsevier.com/locate/jempfin

Heavy tails and currency crises☆

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ARTICLE INFO

Available online 26 September 2009

JEL classification:
G1
F3
C49

Keywords:
Financial crises
Currency market linkages
Heavy tails
Convolutions
Asymptotic dependence

ABSTRACT

In affine models of foreign exchange rate returns, the nature of cross sectional interdependence in crisis periods hinges on the tail properties of the fundamentals' distribution. If the fundamentals exhibit thin tails like the normal distribution, the dependence vanishes asymptotically; while the dependence remains in the case of heavy tailed fundamentals as in case of the Student-*t* distribution. The linearity of the monetary model and heavy tail distributed fundamentals are sufficient conditions for fundamentals-based repeated joint currency crises. An estimator for the extreme exchange rate interdependencies is obtained and applied to Western, Asian and Latin American currency block data.

1. Introduction

In the year 1963 Mandelbrot published two remarkable papers (Mandelbrot, 1963a,b) in which he noted the two important features of speculative price data which gave financial econometricians enough to work on for the subsequent thirty years. The first feature is the Pareto nature of the tails of the distributions of financial returns. Heavy tails in itself were not new to economists, as Pareto himself had discovered this feature in high income data. But for financial economists, who had just discovered the niceties of Brownian motion and were on their way to option pricing, this was novel. In the end it carried the unfortunate message that markets are more likely to be incomplete than otherwise. The positive side of incompleteness is, though, that it gives sufficient motives for active hedging and risk management. The importance of this discovery only came to be fully recognized some thirty years later when banks started to calculate the Value-at-Risk (VaR) measure and had to come to terms with the non-normality of the distribution of financial asset returns. Due to the Pareto nature, the tail probabilities are self scaling, see Feller (1971, VIII.8). This intriguing mathematical phenomenon is very helpful for practical VaR calculations. Upon assuming that the self scaling property applied to the entire distribution, Mandelbrot concluded the distribution of asset returns had to be an infinite variance sum stable distribution.

The second empirical observation reported by Mandelbrot and attributed to Houthakker was the clustering of volatility feature. This data feature lay dormant until Engle's ARCH model (1982) gave a succinct representation which preserved the martingale property of asset prices. The ARCH model nicely implies that even though the innovations are normal, the stationary solution exhibits a Pareto type tail, consistent with the first data feature; see De Haan et al. (1989).

☆ The paper was delivered as a birthday present(-ation) at the Deutsche Bundesbank conference 'Heavy tails and stable Paretian distributions in finance and macro economics' organized in celebration of the 80th birthday of Professor Benoît Mandelbrot. The paper benefited from the insights of the discussant Mico Loretan and Dirk Tasche. We also would like to thank seminar participants in Bath and Maastricht. Finally, we are grateful to the co-editor of the Journal of Empirical Finance and two anonymous referees for their constructive comments.

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0927-5398/$ – see front matter © 2009 Published by Elsevier B.V.
doi:10.1016/j.jempfin.2009.09.004

The 1963 articles also ask the question about the economic mechanism that could be responsible for the noted data features. As of today little work has been devoted to this question, although some early work on income distribution, notably Chapernowne (1953) and some other more recent work, do provide some insight for the marginal distributions to be fat tailed, see e.g. Gabaix et al. (2003). In this article we like to extend the original work of Mandelbrot and subsequent developments by discussing the economics and econometrics of extremes in a multivariate setting. Thirty years later we know a lot more about the univariate issues concerning the heavy tail and summability features. For example, we now realize it suffices to assume the scaling only holds in the tail area. This has the benefit that one does not need to make the infinite variance assumption. But the multivariate issues are wide open for research. The aim of the paper is to show in which direction research is currently evolving.

For this purpose we analyze the multivariate dependency structure in affine models of foreign exchange rate returns. We clarify the cross sectional return dependency during crises by combining the univariate data feature discovered by Mandelbrot with Frenkel's monetary model of the exchange rate. In doing so we do not explain the Pareto tail nature of the univariate series, which we take as given, but we offer an economic explanation for the observed strong crisis spillovers. While fat tails and tail dependence of forex returns have by now been extensively documented in the empirical literature, how the marginal tail thickness relates theoretically to the bivariate and multivariate tail dependence of returns in standard foreign exchange rate models has not been dealt with before. The multivariate questions are certainly new and could hardly have been addressed at the time Mandelbrot was writing his fascinating articles.

There is a long standing discussion about the origins of financial crises. One view holds that such crises are the expression of an occasional inherent malfunctioning of financial institutions or markets (sunspots). Another view rather sees crises as caused by bad outcomes in underlying economic variables (fundamentals). Representative of the first view is the literature modelling univariate crises as self-fulfilling events in the presence of multiple equilibria. For example, Diamond and Dybvig (1983) show that bank depositor runs can occur as a self-fulfilling prophecy, which would imply that they happen more or less randomly. Obstfeld (1986) argues that currency crises can occur as a consequence of multiple equilibria. This is in contrast with the literature which links crises to unfavorable macroeconomic conditions, sometimes caused by bad economic policies. For example, Gorton (1988) argues that most episodes of banking instability in US history were related to business cycle downturns. Krugman (1979) shows how unsustainable large budget deficits can lead to currency attacks. According to Gencay and Selcuk (2006) domestic financial repression may also be an important trigger of emerging currency crashes.[1] Masson (1999) nests most of the previously mentioned channels in a model of contagious currency crises.

In the present paper we do not take a position on the two views of self-fulfilling and fundamentals-based exchange rate crises. Rather, we concentrate on the significance of a crisis. In particular we give sufficient conditions for the repeated occurrence of widespread crises. We use joint currency crashes as an application to illustrate our point, but the argument is more general. It applies to any group of assets whose values are linearly driven by underlying economic variables, or risk factors.

Two basic conditions are sufficient for the frequent occurrence of systemic (widespread) market crises. First, the univariate distributions describing the behavior of economic variables (or 'fundamentals') underlying the exchange rates need to exhibit heavy tails. Loosely speaking, the heavy tail feature means that the probability of univariate currency collapses is approximately Pareto distributed. Mandelbrot's hypothesis of non-normal stable distributions and Student-t distributions exhibit an expansion of their tails in which the first term is a power function like Pareto's distribution. This implies that the probability of a currency crisis is much higher than one would expect if the underlying fundamentals were normally distributed (with the same mean and variance). Second, the (logarithm of) nominal bilateral exchange rates, expressed against the same base currency, are linear expressions of the domestic and the base currency fundamentals. The standard monetary model of the foreign exchange rate provides such an affine framework. The two conditions are shown to imply that joint currency crises will occur frequently and with vehemence. The surprising element of this result is that the degree of cross-sectional dependence between exchange rate returns during crisis periods (so called asymptotic dependence) is related to the univariate characteristics of the tails of the fundamentals' distributions.[2]

One may therefore classify currency linkages during times of market stress into a weak and a strong type, depending on whether the conditional crash probability vanishes or remains asymptotically. Correspondingly, the international monetary and financial system may be characterized as being relatively stable in the former case, while it is more fragile in the latter case. Our two conditions, univariate heavy tails and linearity, are sufficient for a more fragile system. We emphasize that in general the dependency structure of a multivariate distribution and the shape of the univariate distributions are two unrelated concepts. But here the affine economic structure induces that the characteristics of the marginals affect the multivariate dependency structure in a specific way. The same also applies to other asset classes. For example, bank equity returns are asymptotically dependent, if banks hold correlated linear portfolios of partly common, heavy-tail distributed assets, see De Vries (2005).[3]

In the empirical application of the paper, we assess the strength of the asymptotic dependence for panels of industrial (developed) and emerging market currencies by using a simple count based estimator for the extreme interdependencies.[4] The

[1] Gencay and Selcuk also argue that the 2001 Turkish currency crisis could have been expected on the basis of the pre-crisis extreme value distribution of overnight interbank rates.

[2] The cross sectional dependence remains in the tail areas, if the forex fundamentals follow infinite variance sum stable distributions as suggested by Mandelbrot (1963a,b). But we argue that the strong dependence is a more general phenomenon, as it applies to all regularly varying (Pareto type tails) distributed fundamentals.

[3] For a broad survey of the contagion literature based on correlation analysis, see De Bandt and Hartmann (2000).

[4] Recently, a number of studies employed multivariate extreme value analysis to measure extreme asset return linkages, see Hartmann et al. (2004) and Poon et al. (2004). Related bivariate analyses for a single type of asset have recently been carried out on foreign exchange data by Starica (1999) and Hartmann et al. (2003).