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Risk prediction management and weak form market efficiency in Eurozone financial crisis

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ABSTRACT

This paper aims to determine if during the recent European financial crisis European markets are efficient in the weak form, as well to introduce an approach to properly predict daily risk of portfolios composed by these market assets, considering their dependence structure. We use daily data from German, English, French, Greek, Dutch and Belgian markets. We perform variance ratio tests to verify the random walk hypothesis. In a general form European capital markets are efficient referent to past information during current crisis. Moreover, through marginal and Pair Copula Construction models, we predict daily Value at Risk for each market and for the portfolio composed by them. Individual risk predictions are correctly simulated. Simulations performed through PCC model properly predict the composed portfolio risk, highlighting that in this crisis period it is crucial to use a tool enable to make correct predictions about risk. The proposed approach emerges as a solution to this task.

1. Introduction

After a successful starting decade, the Euro zone is heading towards very serious problems and this is partly because of inadequate national policies of some member countries and partly due to a doubtful crisis management (Welfens, 2012). The Eurozone is currently undergoing a crisis of historic importance, which results in accumulation of sovereign debt in the euro zone countries and, moreover, reveals the internal defects of the Eurozone as such (Sapir, 2011). The recent putative crisis in the Euro zone points not so much to an inherent fragility of a common currency and issues with the fundamentals of the Euro currency area, but rather the importance of bank regulation and appropriate sovereign-debt evaluation as a replacement for the arguably haphazard discipline of foreign-exchange markets (Ryan, 2011).

Other distressed euro area sovereigns would face the prospect of a long-term denial of access to capital markets and, at the same time, lower expectations of support over the medium term from the rest of the euro area. A confirmation that the euro area was willing to let one of its members default would inevitably cause investors to reassess the limits of the euro area support. That, together with the assumption that other weak euro area sovereigns might be more likely to choose to take similar steps to Greece could result in Ireland and Portugal, and perhaps stronger countries such as Spain and even Italy and Belgium, finding market access considerably more expensive (Moody's, 2011).

Regarding to capital markets, when great events occur, structure may change due to several factors, especially those of macroeconomic order. No single event has stronger impact on financial markets than a crisis. The global extent of a financial crisis and its potential damaging consequences continuously attract attention among economists and policymakers. Among crisis consequences, we highlight two: the possible reduction in the market efficiency (Kim & Shamsuddin, 2006; Hoque, Kim, & Pyun, 2007; Lim, Brooks, & Hinich, 2008, for instance) which could be caused by lack of liquidity or even other kind of anomaly, and the great difficulty to properly perform risk management (Alexander, Baptista, & Yan, 2012, for instance) because of the rise in turbulence.

About efficiency, stock market predictability has been approached in many studies conducted by researchers from the financial and economic fields. This fact is leveraged by arbitrage possibility, which would result in abnormal gains. In this sense, according to the seminal paper of Fama (1970), when talking about stock market predictability, it should be noted the random walk, which brought important contributions, since it refers to the fact that future returns are independent of past information. Thus, the random walk hypothesis (RWH) carries implications regarding possibility to predict future returns, taking advantage of it to make extraordinary profit. If an asset follows a random walk, it is efficient in the weak form, i.e., past information is already embedded in its price. Too many studies were realized about the random walk hypothesis (see Charles and Darné (2009) and Lim and Brooks (2011) for literature surveys). In the course of these studies, the variance ratio (VR) tests were consolidated as the most popular procedure to verify if a time series is generated by a random walk because the existence of return autocorrelations has strong theoretical justifications, especially in terms of under- or over-reactions to information.

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Regarding to risk management, a crucial issue is the relationship between financial assets. Transmission of shocks to other countries and cross-countries correlations, beyond any fundamental link, has long been an issue of interest to academics, fund managers and traders, as it has important implications for portfolio allocation and asset pricing (Kenourgios, Samitas, & Paltalidis, 2011). Thus, an inappropriate model for dependence can lead to suboptimal portfolios and inaccurate risk exposure assessments. Traditionally, correlation is used to describe dependence between random variables, but recent studies, as that realized by Embrechts, Lindskog, and McNeil (2003), have ascertained the superiority of copulas to model dependence, because a copula function can deal with non-linearity, asymmetry, serial dependence and also the well-known heavy-tails of financial asset marginal and joint probability distribution.

A copula is a function that links univariate marginal to their multivariate distribution. Since it is always possible to map any vector of random variables into a vector with uniform margins, we are able to split the margins of that vector and a digest of the dependence, which is the copula. Despite literature on copulas is consistent, great part of the research is still limited to bivariate case. Thus, constructing higher dimensional copulas is the natural next step, even this being not an easy task. Apart from multivariate Gaussian and Student, selection of higher-dimensional parametric copulas is still rather limited (Genest, Rémillard, & Beaudoin, 2009).

The developments in this area tend to hierarchical, copula-based structures. It is very possible that the most promising of these is the pair-copula construction (PCC). Originally proposed by Joe (1996), it has been further discussed and explored in the literature for questions of inference and simulation. PCC is based on a decomposition of a multivariate density into bivariate copula densities, of which some are dependence structures of unconditional bivariate distributions, and the rest are dependence structures of conditional bivariate distributions. Applications to financial data have shown that these PCC models outperform other multivariate copula models in predicting log-returns of equity portfolios.

Thus, this paper aims to determine if during the recent European financial crisis European financial markets are efficient in the weak form, as well to introduce a form of properly predict the daily risk of portfolios composed by these markets assets, considering their dependence structure. To that, we use data of the German, English, French, Greek, Dutch and Belgian markets. For each market, we perform VR tests to verify the random walk hypothesis. Moreover, through marginal and PCC models, we predict the daily Value at Risk (VaR) for each market and the portfolio composed by them.

The paper has two main contributions for financial literature and market practitioners: i) it extends RWH testing literature on crisis periods for Eurozone debt crisis, in order to identify if one can or cannot obtain arbitrage profits during this turbulent period; and ii) it indicates a statistical tool (PCC) that properly predicts daily risk for a portfolio composed by relevant stock markets directly affected by Eurozone debt crisis, which could be a solution for risk management in this volatile period.

The remaining of this paper is structured as follows: Section 2 presents the material and methods, exposing utilized data and procedures in order to fulfill the proposed objective; Section 3 presents the obtained results and their discussion; Section 4 brings study conclusions; Appendix A exposes the copula families utilized in PCC estimation.

2. Material and methods

We collect daily prices of the DAX (Germany), FTSE (England), CAC (France), GDAT (Greece), AEX (Netherlands) and BFX (Belgic) market index, in the period from May, 2010 to April 2012, totalizing 484 observations. The choice for this period is justified by the fact that it represents the start of the effects due to the current Eurozone crisis, marked through structural change tests by Righi and Ceretta (2011), up to the present date. The number of selected countries is justified by PCC estimation and simulation computational cost, which grows exponentially with dimension number. Further, investment diversification benefits exponentially reduce with portfolio assets number. With this in mind, we opt for six markets. These countries are between the most relevant capital markets in the Eurozone, and the crisis was originated by Greek economic issues. The last 100 observations are reserved for VaR predictions in out-sample analysis.

2.1. Market efficiency analysis

To perform market efficiency analysis during crisis period, we apply VR tests in the logarithmic differences (log-returns) for collected daily prices. The first is the VR test by Lo and Mackinlay (1988). The key feature about this test is that if a variable follows a random walk, its variance for q periods is q times the variance for one period. The VR used in this test is represented by formulation (1).

$$\mathrm{VR}(y;k_i)=\left\{\frac{1}{Tk}\sum_{i=k+1}^{T}\left(y_t+\cdots+y_{t-k}-k\hat{\mu}\right)^2\right\}\div\left\{\frac{1}{T}\sum_{t=1}^{T}\left(y_t-\hat{\mu}\right)^2\right\}. \quad (1)$$

In (1), y_t is an observation from a time series at period t; $\hat{\mu}$ is the mean of y; T is the number of observations; k is the number of lags. Lo and Mackinlay (1988) propose the tests M_1 and M_2. If y_t is independent and identically distributed (*i.i.d.*), then the test M_1 is asymptotically normally distributed. However, this supposition does not stand when there is presence of conditional heteroscedasticity. The M_2 test is robust to this question. M_1 and M_2 tests are represented by formulations (2) and (3), respectively.

$$M_1(y,k_i)=[\mathrm{VR}(y;k)-1]\times\left[\frac{2(2k-1)(k-1)}{3kT}\right]^{-\frac{1}{2}}. \quad (2)$$

$$M_2(y,k_i)=[\mathrm{VR}(y;k)-1]\times\left\{\sum_{j=1}^{k-1}\left[\frac{2(k-j)}{k}\right]^2\delta_j\right\}^{-\frac{1}{2}}. \quad (3)$$

In (3), $\delta_j=\left\{\sum_{t=j+1}^{T}\left(y_t-\hat{\mu}\right)^2\left(y_{t-j}-\hat{\mu}\right)^2\right\}\div\left\{\left[\sum_{t1}^{T}\left(y_t-\hat{\mu}\right)\right]^2\right\}$.

The difficulty of interpretation of these tests is that distinct values for k can change the result. In that sense, Chow and Denning (1993) propose the multiple VR test. This test is represented by formulation (4).

$$MV(y)=\sqrt{T\max_{1\le i\le m}\left|M_{1,2}(y;k_i)\right|}. \quad (4)$$

In (4), $M_{1,2}(y;k_i)$ are the individuals VR tests, exposed in (2) and (3); T is the number of observations. This test follows a student maximus modulus (SMM) distribution with m and T as degrees of freedom.

Wright (2000) proposes non-parametric VR tests based in the rank (R_1, R_2) and sign (S_1) of the variables. These tests are represented by formulations (5), (6) and (7).

$$R_1(k_i)=\left[\frac{(1/Tk)\sum_{t=k+1}^{T}\left(r_{1,t}+\cdots r_{1,t-k}\right)^2}{(1/T)\sum_{t=1}^{T}{r_{1,t}}^2}-1\right]\times\left[\frac{2(2k-1)(k-1)}{3kT}\right]^{-\frac{1}{2}}. \quad (5)$$

$$R_2(k_i)=\left[\frac{(1/Tk)\sum_{t=k+1}^{T}\left(r_{2,t}+\cdots r_{2,t-k}\right)^2}{(1/T)\sum_{t=1}^{T}{r_{2,t}}^2}-1\right]\times\left[\frac{2(2k-1)(k-1)}{3kT}\right]^{-\frac{1}{2}}. \quad (6)$$

$$S_1(k_i)=\left[\frac{(1/Tk)\sum_{t=k+1}^{T}\left(s_t+\cdots+s_{t-k}\right)^2}{(1/T)\sum_{t=1}^{T}{s_t}^2}-1\right]\times\left[\frac{2(2k-1)(k-1)}{3kT}\right]^{-\frac{1}{2}}. \quad (7)$$

The crucial difference between R_1 and R_2, is that $r_{1,t}=r(y_t)-\left[\frac{T+1}{2}/\sqrt{\frac{(T+1)(T-1)}{12}}\right]$ and $r_{2,t}=\phi^{-1}[r(y_t)/(T+1)]$, where $r(y_t)$ is the