Finance Research Letters 000 (2016) 1–8

Contents lists available at ScienceDirect

Finance Research Letters

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

Copula function approaches for the analysis of serial and cross dependence in stock returns

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A R T I C L E I N F O

Article history:
Received 22 October 2015
Accepted 20 January 2016
Available online xxx

JEL classification:
C13
C22
C53
G11

Keywords:
Copula function
Sharpe ratio
Vector AutoRegressive models

A B S T R A C T

The description of the dynamic behavior of multiple time series represents an important point of departure to obtain accurate forecasts both in economic and financial analysis. We provide a method for the comparison of the out-of-sample performance of portfolios, respectively, ignoring and exploiting serial and cross dependence in stock returns. The serial and cross dependence is modeled using both the classical linear and easy-to-use Vector AutoRegressive and more sophisticated models making use of copula functions. After deriving the classical and copula-based VAR conditional expected returns and covariance, we construct different portfolios and compare them in terms of Sharpe ratio in an out-of-sample period.

1. Introduction

It is a stylized fact that financial returns do not show any normal behavior, both in univariate and multivariate case. Moreover, there is empirical evidence of autocorrelation and cross-correlation in stock returns (e.g. Fama and French, 1998; Lo and MacKinlay, 1990). These relationships often appear to be weak, however in some cases they are sufficiently strong to be exploited for the prediction of portfolio returns. Recent works (e.g., DeMiguel et al., 2014) have analyzed the out-of-sample performance of different portfolios selected after solving an optimization problem, using estimates of expected returns and covariance matrix coming from the popular and easy-to-use Vector AutoRegressive (VAR) model. They have showed that such a model can exploit the serial correlation in portfolio

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http://dx.doi.org/10.1016/j.frl.2016.01.006
1544-6123/

returns, as well as the cross correlations, providing the result that portfolios exploiting serial and cross dependence have better performances than portfolios ignoring such a feature.

Actually, the VAR model is able to capture both autocovariance and cross-covariance of stock returns. For this reason it is certainly a valid instrument. However, the limit is given by the fact that the VAR model is a linear model, so it can describe only linear relationships. If a nonlinear relationship holds, the misspecification can lead to wrong conclusions. A nonlinear dependence structure can be captured by a more general model, including the linearity as a special case. The copula function is a challenging approach that enables to manage data in a fairly general context.

The aim of the work is threefold:

1. to relax the classical assumption of multivariate Gaussianity of the innovations of the linear VAR model exploring the more general hypothesis of innovations distributed as a specified copula function. The resulting model keeps the linear relationships among the variables and is called Copula-VAR;
2. to analyze a nonlinear Copula AutoRegressive (Copula-AR) model giving up to the linear structure of the VAR model, and considering a copula function to describe the relationship among the variables. In this case the nonlinear nature of the model is intrinsic and nonlinear serial and cross dependence emerges; and
3. to compare the out-of-sample performances in terms of average returns and Sharpe ratio of portfolios built using estimates of expected values and covariance matrices based on different methods: linear Gaussian VAR, linear VAR with copula errors and nonlinear Copula AutoRegressive model.

In the literature, Bianchi et al. (2010) have proved the predictive ability of the linear Copula-VAR approach in comparison with the classical VAR model using industrial production data. So, they adopt a nonlinear model for innovations joint distribution in a linear VAR framework. Recently, Brechmann and Czado (2015) have proposed the COPAR model, a nonlinear model which exploits the flexibility of vine copulas. We compare these different approaches copula-based in order to investigate serial and cross dependence in stock returns measuring the improvement of the out-of-sample portfolio performance.

Starting from DeMiguel et al. (2014) research method, we have studied the serial and cross dependence among six Fama and French portfolios. Our analysis has showed that a careful modeling of the serial and cross dependence among assets can bring to build portfolios with improving performances over competitor portfolios ignoring or based on simple statistical analyses of the relationships among assets.

The paper is organized as follows. In Section 2 we define the Sharpe ratio and describe the optmization problem for finding the weights of a portfolio. Section 3 focuses on some linear and nonlinear models for capturing the serial and cross correlation among asset returns. In Section 4 an application to real data is carried out. Section 5 concludes.

2. Measures of portfolio performance: the Sharpe ratio

There is a wide range of possible methods for portfolio selection which are strictly linked to the way the performance of a portfolio can be measured (Cogneau and Hübner, 2009). Actually, the weights of the assets composing the portfolio have to be chosen such that the performance measure of interest to be optimized. The well-known Markowitz problem simply searches the weights which minimize the risk of the portfolio, provided some constraints, *in primis* a fixed value of the expected return. However, given that the risk is just an aspect of an investment, it should be more correct to be jointly considered with the return. One of the most popular measures of performance taking into account the trade-off between risk and expected return is the Sharpe ratio (Sharpe, 1966; 1994).

The ex-ante Sharpe Ratio (SR) of an asset A is defined as the ratio of the excess expected return $E(R_A)$ on the expected benchmark portfolio return $E(R_B)$ over its predicted standard deviation σ_A,

$$SR = \frac{E(R_A) - E(R_B)}{\sigma_A}$$

where $E(R_A)$, σ_A and $E(R_B)$ are estimated in a sample period. The SR is widely used for comparing financial performance, also because it is easily interpretable.