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Abstract

The empirical copula has proved to be useful in the construction and understanding of many statistical procedures related to dependence within random vectors. The empirical beta copula is a smoothed version of the empirical copula that enjoys better finite-sample properties. At the core lie fundamental results on the weak convergence of the empirical copula and empirical beta copula processes. Their scope of application can be increased by considering weighted versions of these processes. In this paper we show weak convergence for the weighted empirical beta copula process. The weak convergence result for the weighted empirical beta copula process is stronger than the one for the empirical copula and its use is more straightforward. The simplicity of its application is illustrated for weighted Cramér–von Mises tests for independence and for the estimation of the Pickands dependence function of an extreme-value copula.

Keywords: Copula, Empirical beta copula, Empirical copula, Pickands dependence function, Weighted weak convergence

1. Introduction

In many statistical questions related to multivariate dependence, a crucial role is played by the copula. A basic nonparametric copula estimator is the empirical copula, dating back to [12, 31] and defined as the empirical distribution function of the vectors of component-wise ranks. The asymptotic behavior of the empirical copula has been established under various assumptions on the true copula and the serial dependence of the observed random vectors; see, e.g., [8, 16, 17, 33]. The upshot is that the empirical copula process converges weakly to a centered Gaussian field with covariance function depending on the true copula and the serial dependence of the observations.

Recently, Berghaus et al. [3] investigated the weak convergence of the weighted empirical copula process. They showed that the empirical copula process divided by a weight function, that can be zero on parts of the boundary of the unit cube, still converges weakly to a Gaussian field. As illustrated in the latter reference, this stronger result allows for additional applications of the continuous mapping theorem or the functional delta method. However, this result is only valid for a clipped version of the process. Since the empirical copula itself is not a copula, weak convergence fails on the upper boundaries of the unit cube; see Remark 2.3 in [3].

The empirical beta copula [34] arises as a particular case of the empirical Bernstein copula [see, e.g., 26, 32] if the degrees of the Bernstein polynomials are set to the sample size. In the numerical experiments in [34], the empirical beta copula exhibited a better performance than the empirical copula, both in terms of bias and variance.

In contrast to the empirical copula, the empirical beta copula is a genuine copula, a property that it shares with the checkerboard copula, whose limit is derived in [18] and which is very close to the empirical copula if the margins are continuous. Since the empirical beta copula is itself a copula, it is possible to prove weighted weak convergence for the empirical beta copula process on the whole unit cube. This is the main result of the paper. Weak convergence on the whole unit cube rather than on a subset thereof is quite handy since it allows for a direct application of, e.g., the continuous mapping theorem. In particular, there is no longer any need to treat the boundary regions separately.

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