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Canonical vine copulas in the context of modern portfolio management: Are they worth it? ☆

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ABSTRACT

In the context of managing downside correlations, we examine the use of multi-dimensional elliptical and asymmetric copula models to forecast returns for portfolios with 3–12 constituents. Our analysis assumes that investors have no short-sales constraints and a utility function characterized by the minimization of Conditional Value-at-Risk (CVaR). We examine the efficient frontiers produced by each model and focus on comparing two methods for incorporating scalable asymmetric dependence structures across asset returns using the Archimedean Clayton copula in an out-of-sample, long-run multi-period setting. For portfolios of higher dimensions, we find that modeling asymmetries within the marginals and the dependence structure with the Clayton canonical vine copula (CVC) consistently produces the highest-ranked outcomes across a range of statistical and economic metrics when compared to other models incorporating elliptical or symmetric dependence structures. Accordingly, we conclude that CVC copulas are 'worth it' when managing larger portfolios.

1. Introduction

Equity returns suffer from increased correlations during bear markets (Longin and Solnik, 1995; Longin and Solnik, 2001; Ang and Chen, 2002). This characteristic, known as asymmetric or lower tail dependence, violates the assumption of elliptical dependence that is the basis of modern portfolio theory and mean–variance analysis (Ingersoll, 1987; Markowitz, 1952). While forecasting models incorporating asymmetric dependence produce significant gains for the investor with no short-sales constraints, they have been limited to bivariate or trivariate settings using standard Archimedean copulas (Patton, 2004; Garcia and Tsafack, 2011; Ba, 2011). More advanced flexible multivariate copulas ("vine copulas") introduced by Aas et al. (2009) presents an important opportunity for extending this literature further. Specifically, there are several interesting questions in the context of modern portfolio management. Does the more advanced Clayton canonical vine copula (CVC) produce economic and statistical outcomes superior to that of the Clayton standard copula (SC) in out-of-sample tests? Does the Clayton CVC exhibit superiority above some threshold size of portfolio? Does a more advanced model of the dependence structure produce outcomes superior to that of multivariate normality?

We answer these questions using an out-of-sample, long-run, multi-period investor horizon setting with portfolios comprising up to 12 US industry indices in a tactical asset allocation exercise. It is worth noting that our chosen focus on indices as "assets" delivers an important experimental advantage: collectively the full set of 12 indices constitutes the entire US market index. Thus, due to a binding dimensionality constraint, by employing indices as the basic constituents of the portfolios, our analysis is far more comprehensive than the alternative approach of using individual stocks. Moreover, as each index consists of hundreds of stocks, our investigation effectively involves highly diversified portfolios that exhibit low levels of idiosyncratic risk compared to other applications that form portfolios of individual stocks. Asymmetric dependence is evident regardless of whether an investor has a large number of US stocks within an equity investment portfolio (Ang and Chen, 2002) or is internationally diversified (Longin and Solnik, 2001; Longin and Solnik, 1995). Furthermore, Aggarwal and Aggarwal (1993) show that with 25 securities in a naive portfolio, the degree

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of negative skewness within the portfolio increases significantly and similar evidence is shown by Simkowitz and Beedles (1978) and Cromwell et al. (2000). Therefore, although diversification is prudent financial investment advice for 'normal' times, it becomes questionable when all stocks in the portfolio fall in times of market stress. Moreover, due to asymmetric dependence and negative skewness, the positive effects of diversification are greatly diminished when they are needed most (Chua et al., 2009). Thus, explicitly managing asymmetric dependence could be very worthwhile as investors might require additional compensation for undertaking downside risk (Ang et al., 2006), negative skewness (Simkowitz and Beedles, 1978; Cromwell et al., 2000) and have a preference for positively skewed portfolios (Arditti, 1967).

Our work is most relevant to Patton (2004) and Hatherley and Alcock (2007) who conduct studies upon portfolios of two and three assets respectively over investment horizons of less than a decade. Patton (2004) investigates whether asymmetries are predictable out-of-sample and portfolio decisions are improved by forecasting these asymmetries, as opposed to ignoring them over a single period investment horizon. He shows that investors with no short-sales constraints (i.e., portfolio weights are allowed to be negative) experience economic gains. Hatherley and Alcock (2007) report that managing asymmetric dependence, using a Clayton standard copula (SC) against the benchmark multivariate normal probability model, results in reduced downside exposure. Patton (2009) states that the obvious and perhaps most difficult avenue for future research is the extension of copula-based multivariate time series models to high dimensions. Such a breakthrough came with the CVC technology developed by Aas et al. (2009). The CVC consists of building blocks of pair copula and with a multitude of bivariate copulas from which to choose from, it is now possible to flexibly model the dependence structure for a multivariate joint distribution.

The novelty of our contribution lies in the non-trivial extension of this literature by incorporating methods that allow for higher scalability for capturing asymmetric dependence, with larger data sets over a multi-period investment horizon spanning several decades. Moreover, we apply a broad range of metrics to further investigate economic and statistical performance. We demonstrate how to meaningfully capture asymmetric dependence for higher portfolio dimensions by using the CVC model and mathematically expanding the SC.[1] A multi-period long-term investment horizon study is necessary as Barberis (2000) finds that multi-period decisions are substantially different from single-period decisions due to hedging demands if investment opportunities are time-varying (Merton, 1971). As investors might have different risk preferences, testing portfolio management strategies should include the application of a variety of risk-adjusted measures that incorporate downside risk and robustness against non-linear payoffs. Using an array of metrics to gauge portfolio performance is important as the presence of distributional asymmetries within asset returns can impact investors' portfolio choices (Harvey and Siddique, 2000; Longin and Solnik, 2001; Harvey et al., 2010). More specifically, our work manages asymmetric dependence by using the Clayton CVC that models asymmetric dependence of a portfolio of N assets with $N(N-1)/2$ parameters compared to the Clayton SC that employs just one parameter. Thus, the Clayton CVC, with its higher degree of parameterization, is capable of leading to superior forecasts of equity returns and improved portfolio management decisions. However, much of the forecasting literature indicates that more complicated models often provide poorer forecasts than simple and misspecified models (Swanson and White, 1997; Stock and Watson, 1999). Kritzman et al. (2010) state that practitioners often use simpler models to discriminate amongst investment opportunities, as complex econometric models can suffer from issues such as data mining, poor performance out-of-sample, and failure to produce meaningful profitability in a portfolio management context.

Given this background, our work leads to a deeper understanding of whether the increase in parameterization of an asset portfolio leads to both statistical and economically significant benefits. From a modeling viewpoint, the lower the dimensionality of a model, the higher the reliability of the parameters (Ané and Kharoubi, 2003). Furthermore, the main feature of the CVC compared to the SC is its mathematical scalability for portfolios of high dimensions. Thus, we seek insights into the portfolio size over which the model exhibits superiority. Furthermore, we assess whether the modeling of the dependence structure or the modeling of the marginals has the greater impact on a portfolio. This allows practitioners to understand the areas of a probability model that need to be analyzed further. We also demonstrate a method for building the CVC based on the sums of correlations of assets within the portfolio.

Our results show that for portfolios of 10 constituents and above, our most advanced model that captures asymmetries within the marginals and the dependence structure using the Clayton CVC consistently produces highly ranked outcomes across a range of statistical and economic performance metrics. Economic gains only exist for non-short sales constrained portfolios such as those used by hedge funds. In addition, it produces a returns distribution that exhibits significant positive skewness from a portfolio comprising industry indices that together represent the US market index. This is notable as US industry indices exhibit high levels of negative skewness. Our findings indicate that asymmetries should be incorporated in the modeling of both the marginals and the dependence structure and we find that modeling of asymmetries within the dependence structure has a greater impact than modeling of the marginals for portfolios of higher dimensions.

The paper is organized as follows. Section 2 describes the dataset. Section 3 details the methods used in modeling of the dependence structure and marginals, and the selection of the investor's utility function for portfolio optimization. Section 4 presents and discusses the empirical results of our study and we conclude in Section 5.

2. Data

Our data set consists of US monthly returns on 12 indices, constituting the full US market (data sourced from Ken French's website).[2] The indices are manufacturing (Manuf), other, money, chemicals (Chems), consumer non-durables (NoDur), retail (Shops), consumer durables (Durbl), business equipment, (BusEq), healthcare (Hlth), telecommunications (Telcm), utilities (Util), and energy (Enrgy). Similar to DeMiguel et al. (2009), we calculate arithmetic returns in excess of the US 1-month T-bill. The sample period extends from July 1963 to December 2010, yielding 570 observations in total. The first 120 observations are reserved for the parameterization process for our portfolio management strategy, while the out-of-sample period consists of 450 months from July 1973 to December 2010.

We implement our strategies in portfolios of three, six, nine, ten, eleven, and twelve constituents as shown in Table 1. All indices exhibit excess kurtosis and reject the null hypotheses for the Jarque–Bera test of normality at the 1% level. All indices exhibit negative skewness except for Durbl and Hlth. Durbl exhibits the minimum (−32.97%) and maximum (42.91%) return for our

[1] A detailed introduction to copula theory can be found in Joe (1997) and Nelsen (2006). Other resources for vine copula theory can be found in Aas et al. (2009) and Kurowicka and Joe (2011).

[2] The US market index is the value-weighted return on all NYSE, AMEX and NASDAQ stocks from CRSP. Industry indices are value-weighted returns formed by assigning each NYSE, AMEX, and NASDAQ stock from CRSP to an industry portfolio according to its 4-digit SIC code.