

Information Technology and Quantitative Management (ITQM 2017)

Modeling Dependence between European Electricity Markets with Constant and Time-varying Copulas

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Abstract

This paper investigates the dependence between electricity spot markets at the heart of Europe including France, Germany, Austria and Switzerland based on copula models. Ten different copulas with both time invariant and varying parameters are considered. The empirical results show that time-varying Student-t copula is the best model to fit the sample data. The positive of upper and lower dependence indicates that spot electricity prices in France, Germany/Austria and Switzerland tend to move in the same direction. Also, the results indicate that the dependence between European electricity markets is time-varying and asymmetric, which means that traditional models such as Pearson's correlation are inappropriate to measure the correlations between these markets.

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Peer-review under responsibility of the scientific committee of the 5th International Conference on Information Technology and Quantitative Management, ITQM 2017.

Keywords: Copula; Electricity Spot Price; Dependence

1. Introduction

The European electricity markets are emerging into one single market since electricity markets are becoming more and more intricate with the rapid development of renewable energy. The common market not only guarantees electricity supply for countries of European Union, but also optimizes allocation of electricity, satisfying the consumption of different countries. Several directives, regulations and decisions have been issued to ensure successful reform of markets in member countries. For example, Directive 2003/54/EC obliges openness of the markets and promises access to countries outside the EU. Also, Regulation 1228/2003 helps to reduce difficulties in cross-border trades.

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To identify whether the common market has been successfully established, many researchers have contributed by examining its functioning. Boisseleau analysed the correlation of the day-head spot price of the liberalized European electricity markets and concluded that the level of Europe wide integration of electricity market is quite low [1]. Armstrong and Galli ompared electricity markets in four main Euro countries, France, Germany, Holland and Spain, and found that differences between prices are narrowing and convergence into a single market is in the process [2]. Bunn and Gianfreda presented evidence of increasing market integration through spatial analysis based on electricity markets of Germany, France, Britain, Netherlands and Spain [3]. Balaguer studied electricity markets in the European area in the context of integration between Sweden and Denmark and also confirms the high degree of integration between these two countries [4].

Different from previous studies which mainly focused on modeling the price convergence in electricity markets in different regions to examine the degree of integration of electricity markets in Europe, this paper introduces ways to measure the dependence between electricity day-ahead spot prices of different nations within the European Power Exchange (EPEX SPOT). EPEX SPOT is established to drive forward the integration of European electricity markets and is expected to become the benchmark of the entire European electricity market. By doing so, everyone including producers, suppliers and large industrial consumers will benefit since the transactions will become easier and volatility will decrease. Four countries that trade electricity in the EPEX SPOT, Germany, France, Austria and Switzerland, together account for more than one third of the total electricity consumption in Europe.

In this paper, we draw upon the copula to depict the dependence structure of variables of interest. Sklar (1959) first introduced the copula theory to describe the dependence between variables flexibly [5]. The copula function is powerful since it states that the multivariate distribution function can be decomposed into marginal variables and a density function copula, which completely describes the dependence framework of the variables. After Embrechts et al. (2002) introduced the copula to the area of finance, it has been applied in financial risk management, derivative contracts and portfolio decision problems [6]. Patton (2012) has reviewed the application of copula in financial time series [7].

The rest of this paper is organized as follows. Section 2 outlines the copula models and marginal models. The estimation of parameters of the copula models is also described in this section. In Section 3, we conduct the empirical experiment and discuss the results. Section 4 concludes the paper.

2. Model specification and estimation

2.1. The copula function

The copula function is proposed to measure the dependence of multivariate time series. The copula based multivariate model allows study of the marginal model separately from dependence structure, making it more flexible to specify the model.

To better learn the copula theory, let's start with the Sklar Theorem. Sklar (1959) stated that a two dimensional joint distribution can be decomposed into two univariate marginal distributions and a dependence structure called copula (two dimensional). Given two continuous random variables X and Y , the joint distribution is:

$$F_{XY}(x, y) = C(F_X(x), F_Y(y)) \quad (1)$$

where $F_X(x)$ and $F_Y(y)$ are the marginal distributions of X and Y , respectively, while $F_{XY}(x, y)$ is the joint distribution of X and Y . Set U and V as probability integral transform (PIT) of variable X and Y , respectively, then $U = F_X(X)$, $V = F_Y(Y)$. According to the construction, $C(F_X(x), F_Y(y))$ is a bivariate cumulative distribution function (c.d.f.) with marginal distributions that are uniform (0,1).

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