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硕 士 学 位 论 文

股票市场和外汇市场的相关性研究：基于 Copula 方法

Dependence Structure between the Stock Market and the Foreign Exchange Rate Market via Copula Approach

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摘 要

在金融研究领域，金融资产收益率之间的相关关系一直是重要议题。研究者们通常使用 Pearson 统计量来度量收益率之间的线性相关关系，然而事实上，金融资产收益率之间普遍存在非线性关系，因而，使用 copula 函数来弥补线性测度的缺陷成为当下研究的热点问题。

本文主要使用 copula 函数来研究 2005 年至 2017 年间中国、香港和英国股票市场和外汇市场在极端情况下的联动效应。我们通过 ARMA-GARCH 过程来拟合股票收益率的时间序列和货币收益率的时间序列，同时使用 copula 函数拟合股票收益率和外汇收益率之间的相关关系。我们使用了四种不同的 copula 函数，包括高斯分布、学生 t 分布、Gumbel 分布和 Rotated Gumbel 分布，并且通过 CML 方法来估计，并且采用 AIC、BIC 准则来选择模型。

我们的实证研究表明，在股票收益率和外汇收益率之间存在显著的对称性厚尾相关性。本文采用的方法为刻画金融市场之间的关系提供了更为准确的估计，因而在国际投资、风险管理和资产定价领域都有重要的作用。

关键词：Copula; 相关性; 股票收益率; 外汇收益率

ABSTRACT

The dependence structure between asset returns plays decisive role in financial industry. The main widely used measure is Pearson's linear correlation. However, among other disadvantages it is unable to measure the non-linear dependence across financial assets, which is almost always the case we encounter in reality. To cover shortcomings of ordinary linear dependence, copula functions are used as effective tools.

This paper investigates the extreme concurrent movements in stock –currency return relationship in three markets (China, Hong Kong, the United Kingdom) by applying copulas over the period 2005-2017. The equity-currency univariate returns are developed via ARMA-GARCH models and the relationship between them is determined via use of copulas. To capture different forms of dependence, we compare four copulas: Gaussian, Student's t, Gumbel and Rotated Gumbel copulas. The parametric models of copulas are estimated by the Canonical Maximum Likelihood (CML) method. The model selection is based on the AIC, BIC information criterions.

The empirical results show that symmetric heavy concurrent movements are present between equity market and currency exchange rate market. This finding is valuable in international investment, risk management and asset pricing as it provides more precise estimation of the relationship across financial markets.

Key Words: Copula; Dependence; Equity return; Foreign exchange rate return

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CHAPTER 1 BACKGROUND OF THE STUDY

1.1 Introduction

In the financial world the dependency between asset returns plays crucial role, especially in the field of risk management, finance and portfolio management. Most popular and simple models such as Capital Asset Pricing Model (Sharp, 1964) and portfolio diversification method (Markowitz, 1952) are based on the relationship between financial assets.

The most broadly used measure of dependence is the ordinary linear correlation. It shows only the linear dependence and how strong it is but it doesn't describe the structure of dependence[1]. The Pearson's correlation is a meaningful measure for asset returns only if they follow elliptical distributions such as Gaussian or Student's t distribution. As discussed by Boyer, Gibson and Loretan (1999), the asymmetry in co-movements between assets can't be captured by it. Empirical findings show that the financial data are often non-linear, hence to model the dependence among them alternative methods should be applied.

The main purpose of the thesis is to analyze the dependence structure between stock market and foreign exchange rate market by employing novel and flexible tools such as copula functions. Copulas link together the univariate marginal probability functions to generate the multivariate probability functions. We use dependence

[1] Linear correlation shortcomings are studied by Embrechts, McNeil, and Straumann (2002). Also see Rachev(2009) and Necula(2010)

functions (copulas) for a few reasons. First of all, as Alcock and Hatherley (2007) explained, the univariate marginal models can be estimated separately and there are no requirements for marginal distributions to be elliptically distributed. Thus, when it comes to model specification, we can consider different methods. Second, unlike correlation, copulas don’t change under continuous transformations. That is copula is the same for both returns and logarithm returns. Third, it is capable to capture non-linear dependence as well as asymmetric dependence. Therefore, they are effective for measuring concurrent movements between financial markets.

Our objective is to investigate the dependence between stock market and foreign exchange rate market. What is the dependence structure? Is the dependence symmetric? These are the main questions we investigate here. Many researchers, such as Jondeau and Rockinger (2006) and Wu and Lin (2006), have used ARMA-GARCH and copula models to examine connections between foreign financial markets. In this paper we employed ARMA-GARCH models for each return series and then applied bivariate copula functions in order to determine dependence structure across two financial markets. Among the variety of copulas we adopt four different copulas. Specifically, we select Gaussian, Student-t, Gumbel and Rotated Gumbel copulas to capture different forms of dependence. Furthermore, commonly used AIC and BIC information criterions are used for comparing copula models. The outcome is that there is extreme concurrent movements between stock-currency markets and the dependence is symmetric. These results have significant implications in asset pricing and risk management. In particular, it is useful for risk managers who measure the risk of extreme losses by computing value-at risk (VaR) and ignoring the tail dependence would lead to the underestimation of the risk measure.

1.2 Literature Review

As we discussed in the previous section, the linear correlation is not a reasonable dependence measure for financial data as it has a number of shortcomings. Empirical findings prove that the dependence across some financial markets is stronger during downward extreme co-movements (lower tail dependence) than during upward extreme co-movements (upper tail dependence). It is obvious that in reality observed data are not linear, therefore applying linear correlation to measure the dependence of non-linear data is not reasonable. Embrechts, McNeil, and Straumann (2002) explained the advantages of copulas, considering their ability to capture different types of dependency. As a flexible and simple tool to include all aspects of dependence, many researchers started to employ copula functions. Copulas (dependence functions) were first introduced by Sklar (1959) and were widely used in the Statistics. The studies of Joe (1997) and Nelsen (2006) describe copulas in details. Embrechts, McNeil, and Straumann (1999) brought to light favorable properties of copula functions in the financial field. Due to their property of flexibility, later these functions were applied in risk management (Bouy´e et al. (2000), Klugman and Parsa (2000), Rosenberg and Schuermann, (2006)) and actuarial sciences (Clayton, 1978). Also, a remarkable contribution has Li (2000) in risk management by introducing copula functions in default modeling. Cherubini and Luciano (2001) evaluated VaR by applying

Archimedean copulas.

As useful applications in financial area along with attractive properties mentioned in the previous section, copulas were used by variety of researchers to model the co-movements of international equity market. Jondeau and Rockinger (2006) studied European and US stock markets and found that European equity market has stronger dependence than the US market. Chakrabarti R. and Roll R. (2002) analyzed dependence between European and Asian stock markets during financial crisis and found that the correlation between assets increased immediately before crisis. Necula (2010) discussed the dependence structure between stock markets and found two most suitable copulas for assessing the dependence structure, namely Student t and Clayton-Gumbel copulas. In addition, Cherubini et al (2004), Patton(2006) and Hu(2006) modeled the dependence structure and co-movements via copulas between financial markets.

A signifiacant contribution has Cathy Ning (2010) who studied the dependence structure between stock market and foreign exchange rate market and found that there is significant symmetric tail dependence across those financial markets for 5 countries. Also, Wang et al. (2013) considered the same topic but via dependence –switching copula. He disclosed that the dependence structure is regime-dependent and time-varying. The results of these authors enhances the existing literature and have important implications in risk management and portfolio diversification in global financial markets. Moreover, Reboredo et al. (2016) analyzed the relationship between equity market and currency market by applying copula approach. As a result, he found that there exists positive relationship between stock-currency market with downside and upside spillovers effect.

The rest of this thesis is organized as follows. Chapter 2 presents copula concept and the dependence measures. Chapter 3 provides research methodology, including stationarity and normality of returns, marginal models, bivariate copula models, estimation and model selection methods. Chapter 4 presents the data description. Chapter 5 discusses empirical results of marginal models along with copula models and specifies model selection. Chapter 6 discusses conclusion of the study.

CHAPTER 2 COPULAS AND CORRELATION MEASURES

2.1 The Copula Concept

Copulas are multivariate cumulative distribution functions whose univariate cumulative marginal distribution functions are distributed uniformly on the interval [0, 1]. These functions link univariate marginal distributions to deal with the asymmetry and non-linearity between them. The concept of copulas was defined in Sklar's theorem introduced by Sklar (1959). In this study we consider 2-dimensional or bivariate copulas as our objective is to investigate dependence of equity-currency return markets.

Sklar's theorem: Let S be the bivariate probability function with F_1 and F_2 marginal probability function, than there is a copula C such that

$$S(x_1, x_2) = C(F_1(x_1), F_2(x_2) \qquad (1)$$

for all values of x_1 and x_2 belong to R. If F_1 and F_2 are probability density functions, than C is one and the only one. Contrarily, If F_1 and F_2 are univariate distribution functions, than the S function defined by the above equation is a joint distribution function with F_1 and F_2 marginal distributions.

From the modeling point of view, Sklar's theorem is very effective as we can split the bivariate joint distribution into univariate marginal distributions and a copula cumulative distribution function, which is completely capable to exhibit the dependence structure between two random variables. Moreover, in order to find the joint distribution, it is easier to model the univariate marginal models and then define an appropriate copula, which will describe the dependence structure between them in the best manner.

The main attractive property of copula functions is that they are stable under strict continuous conversions of marginal distributions. Unlike the correlations, the copula is not affected with returns and logarithm returns. This is very important because the transformations are very common in the financial field. The invariance property makes copulas a powerful tool in empirical modeling.

2.2 Dependence Measures

Among frequently used dependence concordance[2] measures are Kendall's tau and Spearman's rho (Kendall, 1938) which are popular because they are capable to measure non-linear dependence, in contrary to linear correlation. Kendall's tau and Spearman's rho are determined[3] through the following equations

$$\tau = \frac{2(c-d)}{n(n-1)} \tag{2}$$

where n is the number of observation pairs, c and d represent number of concordant and discordant pairs respectively.

Similarly, Spearman's rho is defined as

$$\rho = 1 - \frac{6\sum d^2}{n(n^2-1)} \tag{3}$$

where n represents the number of observation duo ranks and d stands for the difference

[2] Two pairs of variables are considered concordant, if the first value from the first pair is smaller(bigger) than the first value from the second pair and the second value of the first pair is smaller(bigger) than the second value of the second pair. Otherwise, these two variables are considered discordant.

[3] Definition is given by Embrecht and his co-authors in 2002

between them.

These dependence measures are broadly used with copulas. The relationship between above mentioned dependence measures and copulas is shown by the following equations

$$\rho_\tau = 4 \iint_0^1 C(u, \mathrm{v}) dC(u, \mathrm{v}) - 1 \tag{4}$$

$$\rho_s = 12 \iint_0^1 C(u, \mathrm{v}) du d\mathrm{v} - 3 \tag{5}$$

It is obvious that there is no dependence between these measures and marginal distributions, hence we can compare models by referring on common Kendall’s tau and Spearman’s rho. Kendall’s tau is calculated by taking into account concordant and discordant pairs and Spearman’s rho is calculated by considering deviations.