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Modeling dependence structures among international stock markets: Evidence from hierarchical Archimedean copulas

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ABSTRACT

This study investigates dependence structures among international stock markets, including developed, emerging, and frontier markets, using the hierarchical Archimedean copula model. Empirical results indicate that emerging markets show the strongest dependence with European markets. Frontier markets show the weakest dependence with other market. After the global financial crisis, the lower dependence structure among the international stock markets has changed. Negative news have a larger impact on the degree of dependence than positive news. Contagion effect is observed in both the global financial crisis and the EU debt crisis.

1. Introduction

The past few decades have witnessed a steady rise in studies of the economies and finance in traditional emerging markets. However, frontier markets, new emerging markets with characteristics less developed than those of traditional emerging markets, are now attracting the attention of global investors. Although frontier markets are smaller and less accessible than traditional emerging and developed stock markets, they are still investable because of their high value potential. Frontier markets are not only growing in importance, as evidenced by the recent listings of new mutual funds and exchange-traded funds, but also rapidly developing in economic and financial terms. Therefore, understanding the dependence structure among international equity markets, including developed, traditional emerging, and frontier markets, is of increasing significance to global investors for managing asset allocation and risk and planning diversification strategies.

Most research on international equity returns focuses on the relationships between developed and emerging markets (see Long et al., 2014; Yang and Hamori, 2013; Zhang et al., 2013) or between emerging and frontier markets (see Baumöhl and Lyócsa, 2014; De Groot et al., 2012; Samarakoon, 2011). For example, De Groot et al. (2012) stated that value, momentum, and local size returns in frontier markets cannot be explained by global risk factors. Mensi et al. (2014) documented that the global financial crisis influenced the dependence structure between emerging markets and global stock and commodity markets.

However, by comparison, research on the relationships among developed, traditional emerging, and frontier markets is limited. For example, Samarakoon (2011) found that interdependence is driven more by U.S. shocks, while contagion, by emerging market shocks. In addition, frontier markets also exhibit interdependence and contagion[1] to U.S. shocks. Baumöhl and Lyócsa (2014) estimated an asymmetric dynamic conditional correlation (DCC) between traditional emerging and frontier markets.

Previous studies of co-movement dynamics in international stock markets have been based on generalized autoregressive conditional heteroscedasticity (GARCH) and vector autoregressive (VAR) models.[2] However, the main drawback of these approaches is their restricted linear correlation coefficients, which cannot correctly capture the dependence structure among assets.

Sklar's (1959) theorem introduced copula functions, which allow us to combine univariate distributions to obtain a joint distribution with a particular dependence structure. However, to better quantify market

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[1] Interdependence refers to the phenomenon that group members are mutually dependent on the others. In this study, we investigate dependence among developed, traditional emerging, and frontier markets. Contagion refers to the strong co-movement of financial markets across countries after the global financial crisis.

[2] There are other ways to show that markets are dependent. For example, there is a large literature now on stock market return predictability. It seems from this literature that both macroeconomic/institutional factors (Narayan et al., 2014; Westerlund et al, 2015) and governance factors (Narayan et al., 2015) are able to predict emerging market stock returns.

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risks, asset volatility and dependence structure should be considered. The copula-GARCH (C-GARCH) model is a multidimensional GARCH process that models the dependence structure by using a copula function. The application of the C-GARCH model has recently attracted increased academic attention (see Jondeau and Rockinger, 2006; Yang and Hamori, 2013). For instance, Yang and Hamori (2013) evidenced that emerging markets are sensitive to external negative news (downside risk) from developed markets and that the process of dependence changes during crisis periods.

This study advocates the use of the hierarchical Archimedean copula (HAC)-based multivariate GARCH (HAC-MGARCH) model to describe the dynamic dependence among developed, emerging, and frontier markets. The shortcoming of traditional copulas is that they cannot easily model the dependence structure of three or more variables. However, because HACs overcome this weakness, we employ the HAC-MGARCH model to specify the dependence structure among international stock markets.

Unlike previous research, this study considers changes in the dependence structure of three types of stock markets: developed, emerging, and frontier markets. To accomplish this, Morgan Stanley Capital International (MSCI) indexes are used since they can provide representative results. Moreover, employing the HAC-MGARCH model allows us to investigate the dependence structure of three or more markets (developed, emerging, and frontier markets). To do so, the developed market here is treated differently according to its location, considering information transmission.

The remainder of this paper is organized as follows. Section 2 discusses the methodology used in this paper. Section 3 describes the data and statistical issues. Section 4 provides the empirical results. Section 5 concludes.

2. Methodology

This study estimates the marginal distributions of data series by using the (AR)(k)-GARCH(p, q) model. By using the estimated marginal distributions, HAC (Okhrin et al., 2013) is employed to investigate the dependence structure among international stock markets. In addition, the marginal joint distribution from HAC is used to model the conditional correlations among international stock markets.

2.1. Marginal specifications

Dependences among international stock markets can be examined by combining copula functions with a GARCH-type model (Bollerslev, 1987; Engle, 1982) of conditional heteroscedasticity. This model not only successfully describes the characteristics of volatility clustering in stock returns,[3] but also eliminates serial dependence from the component time series. The AR(k)-GARCH(p, q) specification is expressed as follows:

$$r_{it} = C_i + \sum\nolimits_{j=1}^{k} AR_i r_{i,t-j} + \varepsilon_{it},\;\; E_{t-1}(\varepsilon_{it}) = 0,\;\; E_{t-1}\left(\varepsilon^2_{i,t-1}\right) = h_{it} \qquad (1)$$

and

$$h_{it} = \omega_i + \sum\nolimits_{j=1}^{p} \alpha_j \varepsilon^2_{i,t-j} + \sum\nolimits_{j=1}^{q} \beta_j h_{i,t-j} \qquad (2)$$

where E_{t-1} is the conditional information operator based on the information at time $t-1$. Eq. (1), the AR(k) model, indicates that the current movement of a variable x_t can be explained by its own past movement (x_{t-1}, x_{t-2}, ⋯). In this paper, the variable r_{it} is represented by the i–th asset return at time t. Eq. (2) denotes that each volatility has a GARCH(p,q) process.

Since the error term ε_t expressed are skewed and heavy tailed, the density function of ε_t is assumed to follow a Student's t distribution[4]:

$$f(t) = \frac{\Gamma\left(\frac{\nu+1}{2}\right)}{\sqrt{\nu\pi}\,\Gamma\left(\frac{\nu}{2}\right)}\left(1+\frac{t^2}{\nu}\right)^{-\frac{\nu+1}{2}}, \qquad (3)$$

where v is the number of degrees of freedom and Γ is the gamma function. The Ljung–Box Q test is applied to examine the residuals of the AR term. According to Schwarz's Bayesian information criteria and residual diagnostics, the values of k, p, and q are such that $k = 1, 2..., 5$; $p = 1, 2$; and $q = 1, 2$.

2.2. Copula functions

Copulas are increasingly used to model multivariate distributions with continuous margins in various research fields, particularly finance (Aloui et al., 2013; Chollete et al., 2011; McNeil et al., 2005; Zolotko and Okhrin, 2014). The recent surge in the popularity of this model in finance studies can be attributed to Sklar (1959), which remains the cornerstone of the theory of copulas. Following Sklar's (1959) studies, we assume $X = (X_1,...,X_d)$ is a random vector with continuous marginal cumulative distribution functions $F_1,...F_d$ and joint distribution H. Sklar (1959) showed that the joint distribution H of X can be represented as

$$H(X) = C(F_1(x_1), \ldots, F_d(x_d)) \qquad (4)$$

in terms of a unique function $C : [0, 1]^d \rightarrow [0, 1]$, which is called a copula.

Copula functions can conveniently construct a multivariate joint distribution by first specifying the marginal univariate distributions and then investigating the dependence structure between the variables according to different copula functions. In addition, tail dependence can be well described by copulas. Two measurements are generally applied to evaluate tail dependence, namely the upper and lower tail dependence coefficients, which function well regardless of whether the markets are crashing or booming.

By assuming that X and Y are random variables with marginal distribution functions F and G, the coefficient of lower tail dependence λ_L can be computed as follows:

$$\lambda_L = \lim_{t\rightarrow 0+} P_r\left[Y \le G^{-1}(t) | X \le F^{-1}(t)\right], \qquad (5)$$

which measures the probability of observing a lower Y if the condition of X itself is lower. On the contrary, the coefficient of upper tail dependence λ_U can be estimated by

$$\lambda_U = \lim_{t\rightarrow 1-} P_r\left[Y > G^{-1}(t) | X > F^{-1}(t)\right]. \qquad (6)$$

When the value of lower tail dependence is the same as that of upper tail dependence, there is "symmetric tail dependence" between the two variables; in other cases, dependence is asymmetric. This approach is, thus, an efficient way in which to order copulas. Moreover, if the λ_U of C_2 is greater than the λ_U of C_1, copula C_2 is more concordant than copula C_1.[5]

This study considers two types of Archimedean copulas: Gumbel and Clayton. In practice, the class of Archimedean copulas has proven to be convenient to model a wide variety of dependence structures because

[3] Using the GARCH model to deal with conditional heteroskedasticity allows us to ensure that the HAC structures are more robust.

[4] The t distribution is selected on the basis of the Jarque–Bera test results.

[5] The concordant pair indicates the elements of one pair are greater than, equal to, or less than the corresponding elements of the other pair.