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Greek Crisis, Stock Market Volatility and Exchange Rates in the European Monetary Union: A Var-Garch-Copula Model

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GREEKCRISISSTOCKMARKETVOLATILITYANDEXCHANGERATESINTHEEUROPEANMONETARYUNIONAVARGARCHCOPULAMODEL

Strictly as per the compliance and regulations of:

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Adel Boubaker [α] & Jaghoubbi Salma [σ]

Abstract- The main objectives of this study are twofold. The first objective is to examine the volatility spillover between seventeen European stock market returns and exchange rate, over the period 2007-2011, in a multivariate setting, using the VAR (1)-GARCH (1,1) model which allows for transmission in returns and volatility. The second is to investigate the dependence structure and to test the degree of the dependence between financial returns using two measures of dependence: correlations and copula functions. Five candidates, the Gaussian, the Student's t, the Frank, the Clayton and the Gumbel copulas, are compared. Our empirical results for the first objective suggest that past own volatilities matter more than past shocks (news) and there are moderate cross market volatility transmission and shocks between the markets. Moreover, the result on the second objective implies that, considering all the financial returns together, the Student-t copula seems the best fitting model, followed by the Normal copula, both for the two sub-period. The dependence structure is symmetric and has non-zero tail dependence. However, if we examine the relationship between each pair of stock-FX returns, both of the degree of the dependence and the dependence structure vary when the financial Greek crisis occurs. Our findings have important implications for global investment risk management by taking into account joint tail risk.

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I. Introduction

Understanding the dependence structure across international financial markets remains a crucial issue for risk management and portfolio management. Several studies have focused on the co-movement of world exchange indices during a worldwide financial crisis. Moreover, many researchers have investigated the relationship among worldwide financial markets. There is a great deal of research focusing on the co-movements of international equity markets. Following the stock market crash of October 1987 in the United States, King and Wadhwani (1990) tried to explain why, in October 1987, almost all financial markets collapsed together despite different economic contexts. In 1996, Calvo and Reinhart estimated that the co-movements of weekly equities returns and Brady bonds, in Asia and Latin America, were higher after the crisis. Baig and Goldfajn (1999) investigated the links between five financial markets which are Thailand, Malaysia, Indonesia, Korea and the Philippines. They tested the statistical significance of the increase in correlation coefficients of exchange markets equity, interest rate and sovereign debt. They confirmed the contagion effect only in Thailand and Malaysia. However; they found that Thailand had not played an important role in the process of contagion during the Asian crisis. Forbes and Rigobon (2002) attempted to test the existence of contagion effect during the following crisis: the U.S stock market crash of 1987, the Mexican peso crisis in 1994 and the crisis in South East Asia in 1997 using daily return data. They showed that the correlation between different countries is not significantly higher during crises. Besides, other examples of research on the co-movements of equity markets can be found in Karolyi and Stulz (1996) and Longin and Solnik (2001), while the methodology used is along the line of correlations and conditional correlations. However, several empirical studies, such as Boyer and al. (1999), Forbes and Rigobon (2001) and Corsetti and al. (2002) showed that the use of the high frequency financial series indicates three types of the bias, because of heteroskedasticity, endogeneity and other omitted variables. Since these limitations of correlation-based models, research has started to use copulas to directly model the dependence structure across financial markets. Works along this line include Rochand Alegre (2005) who tested different structures of dependence, including different type of copulas: the Gaussian, the t-Student and seven other Archimedean copulas to model the dependence of Spanish market returns. Their results reject the Gaussian copula in almost all cases and among the nine structures considered. Moreover, the Student-t-copula provides the best results. Jondeau and Rockinger (2006), Bartram and al. (2007) and Dimitris Kenourgios Aristeidis Samitas (2011) estimate the conditional copulas in order to model the dependence between the major market indices. They report asymmetric extreme dependence between equity returns. Boubaker, A., and Jaghoubi, S., (2011) employ the student-t- copula to model the dependence structure of among a sample of

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eight emerging and eight developed markets. Their results show that this new approach proves more appropriate to describe the non-linear and complex dynamics of the financial market returns than traditional modeling which imply a normality hypothesis. In addition, they confirm the contagious nature of the Subprime crisis between emerging and developed markets. While the above literature focuses on the dependence structure and co-movements in equity markets via copulas, Okimoto (2008) also employs copulas to model the asymmetric exchange rate dependence between US-UK and find that this regime is best described by asymmetric copula with lower tail dependence. Although there is wide literature analyzing the co-movements and the interdependence between the international equity markets and some literature on modeling the dependence structure between the exchange rates via copulas, few use copulas to study the co-movements across markets of different asset types, such as the stock market and foreign exchange rates.

The purpose of this paper is to examine the dynamic correlation and volatility transmission between the European Monetary Union and the FX returns and to explore the dependence structure between daily stock returns, after the occurrence of the current financial Greek crisis. Our paper has similarities and differences with the previous literature. The main similarity is that we try to estimate dependence of financial markets. However, there are several main differences. First of all, while previous empirical investigations of the link between FX markets and stock prices are mainly devoted to developed markets, and sometimes to Pacific Basin countries, our interest is focused on European markets that are member of euro-area and were affected by recent financial Greek crisis. Second, we assess dependence using both correlation and copula functions, and we are agnostic ex ante about which technique is appropriate. Third, unlike most studies in the literature that directly model the dependence structure between FX rates and stock prices, using copula approach, we attempt to estimate this dependence by combining two models which are the VAR- GARCH(p,q) and the Copula techniques to have a joint VAR- GARCH-COPULA model with possibly skewed, fat tailed return innovations and non-linear property. Although, the vector autoregressive–generalized autoregressive conditional heteroskedasticity model (VAR-GARCH)is used to explore the joint evolution of conditional returns, volatility and correlation between the European stock market returns and the exchange rate over the Greek crisis period, the multivariate dependence structure between markets is modeled by several copulas which are perfectly suitable for non-normal distributions and nonlinear dependencies.

The remainder of this paper is organized as follows: Section 2 presents the theoretical background of the dependence measures used in empirical finance and shows how they can be applied to study the extreme co-movements between the European markets. In Section 3, the empirical results are reported and interpreted. We provide summary of our conclusions in Section 4.

II. Methodology

Our methodology is based, primarily, on the calculation of linear and rank correlation coefficients between the European market returns. We get series of correlation coefficients between these markets and we study their dynamics changes. Secondly, such as measurements based on linear correlation may lead to misspecification of the dependence structure with its nonlinear portion, copula approach is employed to provide the robust measures of dependences based on the entire joint distributions of variables and also to estimate dependence focuses on the entire structure rather than correlation. Besides, as the copula functions are used to separate the margins and the dependence structure corresponding to a joint distribution, we estimate, in the first step, the parameters of marginal distributions and those of returns and volatilities equations. Then, in the second step, the parameters of the copula taking into account the parameters estimated in the first step.

a) Correlations

Correlations are the most familiar measures of dependence in finance. Although most studies have focused on measuring the dependence between financial markets have used the Pearson correlation, this coefficient is only reliable when the random variables are jointly Gaussian. Therefore, we consider two other measures of dependence: the Kendall's tau and the Spearman's Rho, which are measures of concordance, generalize the linear correlation, taking into account the joint distribution (and not just marginal) and are dependent on copulas. The rate of Kendall and Spearman's rho are two measures of concordance well known in statistics. They provide a measure of the correlation between the ranks of the observations, unlike the linear correlation coefficient which assesses the correlation between the values of observations. It is necessary to recall the notion of concordance. Let (x, y) and $(\tilde{x}, \tilde{y})$ two realizations of a continuous random vector (X, Y), then (x, y) and $(\tilde{x}, \tilde{y})$ are called concordant if $(x-\tilde{x})(y-\tilde{y}) > 0$ and discordant if $(x-\tilde{x})(y-\tilde{y}) < 0$.

- The Kendall correlation coefficient

Let (X, Y) a couple of random vectors and (X', Y')a copy of (X, Y) that is to say a pair of vectors in all respects identical to (X, Y) the Kendall's tau is then:

$$\rho_\tau\,(X, Y) = \Pr\{(X - X')(Y - Y') > 0\} - \Pr\{(X - X')(Y - Y') < 0\} \quad (3.2)$$

The Kendall's tau is simply the difference between the probability of concordance and of discordance.

- The Spearman correlation coefficient

Let X and Y are two random variables of marginal distributions $F_X et F_Y$. The correlation coefficient Spearman rank coefficient ρ_s is the Pearson correlation ρ between $F_X(X)$ and $F_Y(Y)$:

$$\rho_s(X,Y) = \rho\,(F_X(X), F_Y(Y)) \quad (3.3)$$

b) A copula model for asymmetry dependence

Copulas are multivariate distribution functions with standard uniform marginal distributions. Am-dimensional copula is represented as follows:

$$C\,(u) = C\,(u_1, \ldots, u_m) \quad (3.5)$$

Where $u_1, \ldots, u_m$ are standard uniform marginal distributions. In such a context, copulas can be used to link margins into a multivariate distribution function. The copula function extends the concept of multivariate distribution for random variables which are defined over [0,1]. This is possible due to the Sklar (1959) theorem which states that copulas may be constructed in conjunction with univariate distribution functions to build multivariate distribution functions.

Sklar's Theorem: Let F_{XY} be a joint distribution function with margins F_X and F_Y. Then there exists a copula C such that for all x, y in R,

$$C\,(u_x, u_y) = C\,(F_x(x), F_y(y)) = F\,(F_x^{-1}(u_x), F_y^{-1}(u_y)) \quad (3.6)$$
$$C\,(u_x, u_y) = F\,(x, y)$$

If F_X and F_Y are continuous, then C is unique; otherwise, C is uniquely determined on Ran $F_X \times$ Ran F_Y and C is invariant under strictly increasing transformations of the random variables. Our model aims at capturing the type of asymmetric dependence found in financial markets. For that, two models are specified: the marginal distribution model and the joint distribution model.

i. *Specification of the marginal distribution*

For marginal distributions, we use a bivariate VAR(1)-GARCH(1,1)[1] model developed by Ling and McAleer (2003)which allows for spillover effects in both returns and conditional volatilities to examine both own conditional volatility for each market and conditional cross market volatility transmission among European Monetary Union (EMU) and the FX rate.

The conditional mean equation of the VAR (1)-GARCH (1, 1) system is giving by:

$$\begin{cases} y_t = c + \emptyset y_{t-1} + \varepsilon_t \\ \varepsilon_t = h_t^{1/2}\eta_t \end{cases} \quad (3.7)$$

Where

- $y_t = (R_t^{EMU}, R_t^{FX})$; R_t^{EMU} and R_t^{FX} are the returns on the EMU and FX market indices at time t, respectively.
- $\varepsilon_t = (\varepsilon_t^{EMU}, \varepsilon_t^{FX})$; ε_t^{EMU} and ε_t^{FX} are the residual of the mean equations for the EMU and FX markets returns, respectively.
- $\eta_t = (\eta_t^{EMU}, \eta_t^{FX})$, refers to the innovation and is an i.i.d distributed random vectors.
- $h_t^{1/2} = \text{diag}\,(\sqrt{h_t^{EMU}}, \sqrt{h_t^{FX}})$; with h_t^{EMU} and h_t^{FX} being the conditional variances of R_t^{EMU} and R_t^{FX}, respectively given by:

$$h_t^{EMU} = c_{EMU} + \alpha_{EMU}\,(\varepsilon_{t-1}^{EMU})^2 + \beta_{EMU} h_{t-1}^{EMU} + \alpha_{FX}\,(\varepsilon_{t-1}^{FX})^2 + \beta_{FX} h_{t-1}^{FX} \quad (3.8)$$

$$h_t^{FX} = c_{FX} + \alpha_{FX}\,(\varepsilon_{t-1}^{FX})^2 + \beta_{FX} h_{t-1}^{FX} + \alpha_{EMU}\,(\varepsilon_{t-1}^{EMU})^2 + \beta_{EMU} h_{t-1}^{EMU} \quad (3.9)$$

From these two equations above, we can see how volatility is transmitted over time across the EMU and the FX markets. Thus, the past shock and volatility of one market are allowed to impact the future volatility not only of itself but also of all other markets in the system.

ii. *Specification of the dependence structure*

Here we study five copulas with different dependence structure: the Gaussian copula, the Student-tcopula, the Frank copula, the Clayton and the Gumbel copula. From them, the Gaussian copula is the most popular in finance and used as the benchmark. The following table shows the characteristics of the best known models where the parameter C_R *is* the distribution function of joint variables, v *is* the degree of freedom, $\sum$ is the variance-covariance matrix, the parameter θ measures the degree of dependence between risks.

[1] See Chan et al. 2005; Hammoudeh et al., 2009 and Arouri et al., (2011) for further details about the VAR-GARCH model.

Table 1 : Copulas models

Noun	Parameters	Copulas
Gaussian	R	$C_R(u_1, \dots\dots . u_m) = \emptyset_R(\emptyset^{-1}(u_1), \dots\dots\dots, \emptyset^{-1}(u_m))$
Student	R, v	$C_T(u_1, \dots, u_m) = T_{v,m,\Sigma} \; (T_v^{-1}(u_1), \dots, T_v^{-1}(u_m))$
Clayton	$\theta > 0$	C (u, v,θ) $= (u^{-\theta} + v^{-\theta} - 1)^{\frac{-1}{\theta}}$
Gumbel	$\theta \geq 1$	C (u, v,θ) = exp $[-[(-\mathrm{Ln}\,(\mathrm{u}))^{\theta} + (-\mathrm{Ln}\,(\mathrm{v}))^{\theta}]\,]^{\frac{1}{\theta}}$
Frank	$\theta \neq 0$	C (u, v,θ) = - $\frac{1}{\theta}$ Ln [1+ $\frac{(\exp(-\theta_u)^{-1})(\exp(-\theta_v)^{-1})}{\exp(-\theta)-1}$

III. Data and Results

a) Descriptive statistics

We use daily market data from seventeen European stock market indices, for a sample period of February 1, 2007 to December21, 2011. We choose this period to investigate the impact of the 2009 Greek crisis on the rest of European monetary countries. The countries used in our sample are France (CAC40), Germany (DAX), Belgium (BEL-20), Spain (IGBM), Ireland (ISEQ), Italy (FTSE MIB), Luxembourg (LUX GENERAL), the Netherlands (AEX), Ostrich (ATX), Portugal (PSI20), Finland (OMX H25), Greece (ATHEN COMPS), Slovenia (SBI TOP), Cyprus (CYSE GENERAL), Malta (MSE), Slovakia (SAX) and Estonia (OMXT). The total number of observations is 1253for the full sample. We briefly overview summary statistics, then discuss the correlation and copula estimates.

Table 2 : Descriptive statistics of daily stock prices and foreign exchange rates

Stock and FX returns	Mean	S.D	Skewness	kurtosis	Jarque-Bera
CAC40	-0.021238	0.779427	0.139538	7.969773	1289.906 [0.000]
DAX	-0.005244	0.746523	0.118501	8.201018	1414.069 [0.000]
BEL-20	250412.4	138032.6	-0.370712	2.493563	2286.917 [0.000]
IGBM	-0.022659	0.785953	0.240945	8.821721	1777.869 [0.000]
ISEQ-20	-0.041144	0.905208	-0.400758	8.079340	1379.045 [0.000]
FTSE-MIB	-0.038663	0.819882	0.042126	7.258653	944.1836 [0.000]
LUXx	0.001546	0.000965	1.588051	4.654095	649.3023 [0.000]
ATX	1.152728	24.24244	20.33048	415.0361	8928443 [0.000]
PSI 20	-0.027363	0.643563	-0.013060	9.880040	2465.221 [0.000]
OMX H25	-0.016295	0.793113	0.101068	5.686303	377.7563 [0.000]
ATHEN. COMPOS	-0.068151	0.901909	0.168730	6.378040	602.4575 [0.000]
SBI-TOP	0.046487	0.378522	-0.170289	10.76016	3145.580 [0.000]
CYSE	0.018518	0.974732	-0.021023	7.124780	885.2031 [0.000]
MSE	-0.017356	0.305635	0.065548	9.336490	2088.362 [0.000]
SAX	0.023580	0.595649	1.592428	42.12614	60751.30 [0.000]
OMXT	-0.022058	0.657041	0.165734	8.714507	1708.529 [0.000]
EURO/USD	9.05E-05	0.316340	-0.192636	6.300257	577.9667 [0.000]

The returns are in national currencies. The sample contains daily market returns from February 1, 2007 until December 21, 2011. The values in parenthesis are the probability values.

The descriptive statistics for daily returns shown in **table 2** suggest that the mean daily stock returns range between-0.068151 and 250412.4 and the standard deviation between 0.000965 and 138032.6. Jarque-Beratests on log returns data indicate that the normality hypothesis cannot be accepted for these stocks, Furthermore, European stock market returns and exchange rates show the properties of asymmetry, leptokurtosis, and tail dependence; hence, the normality assumption has been severely challenged.

b) Empirical results

i. Correlation estimates of dependence

Table 3 presents linear correlations, the Kendall's tau and the Spearman's rho rank correlations between the stock and the exchange rate return pairs, before the financial Greek crisis. We observe that the pair wise correlations are positive for France, Germany, Belgium, Cyprus, Estonia, The Netherland, Finland, Ireland, Luxemburg, Portugal, Slovakia and Slovenia, indicating that the increase (decrease) of the local stock market is associated with the appreciation (depreciation) of the exchange rate EURO/USD. The Kendal's Taus for our pairs of stock market returns and stock exchange rate are all positive, expect for Malta, Ostrich, Athens, Spain, Slovenia, Portugal and Slovakia; showing the probability of concordance is significantly higher than the probability of discordance. The Spearman's Rhos for the pairs in each country are also positive for eleven countries from seventeen which are France, Germany, Belgium, Ireland, Italy, Cyprus, Estonia, the Netherland, Finland, Portugal and finally Luxemburg. However, the Spearman Rhos are negative for the rests of European markets. From these results, we can conclude that there are strong rank correlations. The German pair has the strongest dependence, followed by the Finland pair and the French pair. However, the weakest is in the Spanish pair.

Table 3 : Correlation measures (2007-2009)

Pairs	Pearson correlation	Kendall's Tau	Spearman's Rho
French pair	0.217002*	0.120057*	0.178925*
German pair	0.241257*	0.127205*	0.191042*
Maltin pair	-0.013309	-0.002404	-9.58$E^{-0.4}$
Belgium pair	0.159411*	0.08665	0.128747*
Irish pair	0.015392	0.021143	0.034781
Austrian pair	-0.053048	-0.050691	-0.072301***
Greek pair	-0.038951	-0.022945	-0.029832
Italian pair	0.093629*	0.048453	0.075733**
Spanish pair	-0.08543**	-0.052023	-0.073413
Slovenian pair	0.007018	-0.002555	-0.001342
Cyprus' pair	0.048925	0.005701	0.0095
Estonian pair	0.118461*	0.059192	0.090004*
The Netherland's pair	0.214112*	0.120367*	0.179963*
The Finnish pair	0.222949*	0.148791*	0.219887*
Luxemburg's pair	0.035408	0.021129	0.037361
Portugal's pair	0.020022	-8.26 $E^{-0.4}$	0.02933
Slovaquie pair	0.014043	-0.005785	-0.007046

*This table gives different correlation measures for each stock-EUR/USD exchange rate daily return pair over the period February 1, 2007 to October 15, 2009. *, **, *** denote significance level at the 1%, 5% and 10% respectively. Total observations are 691.*

In table 4, we present these linear correlations and rank correlations measures for each stock-exchange rate return pair after the current financial Greek crisis. The linear correlation, Pearson coefficients, for our pairs of returns are all positive, expect for the Cyprus market, showing that, for these sixteen European markets, the increase (decrease) of the local stock market is associated with the appreciating (depreciating) of the exchange rate EURO/USD. Besides, for the Cyprus, when the CYSE price increase (decrease), the EURO/USD exchange rate depreciate (appreciate). Thus, the Cyprus stock market return and the exchange rate evolve in a reverse sense. The Kendall's Taus for our pairs are all positive expecting for Cyprus, Luxemburg and Slovakia indicating that the probability of concordance is higher than the probability of discordance. The Spearman's Rhos indicate strong rank correlations. The values of Taus and Rhos are consistent with each other and the linear correlation. The Spanish market has the strongest dependence with the EURO/USD exchange rate, followed by the French pair, and the weakest is the Cyprus which has a negative dependence with the exchange rate. Further, the correlation increase and became strong in the post-crisis period. Thus, the stock-exchange rate returns become more dependent when financial extreme events (Greek crisis) occurs.

Table 4 : Correlation measures (2009-2011)

Pairs	Pearson correlation	Kendall's Tau	Spearman's Rho
French pair	0.399639*	0.261639*	0.38908*
German pair	0.366664*	0.241558*	0.355483*
Maltin pair	0.010872	0.001135	0.005995
Belgium pair	0.328631*	0.231164*	0.338939*
Irish pair	0.309094*	0.186582*	0.281274*
Austrian pair	0.394895*	0.243991*	0.360439*
Greek pair	0.356695*	0.230517*	0.3457*
Italian pair	0.193274*	0.119417**	0.180844*
Spanish pair	0.421876*	0.278678*	0.411704*
Slovenian pair	0.071381***	0.039933	0.063891
Cyprus' pair	-0.066602*	-0.052188	-0.071521***
Estonian pair	0.026679	0.0021	0.00999
The Netherland's pair	0.366036*	0.236823*	0.349146*
The Finnish pair	0.358086*	0.232382*	0.343484*
Luxemburg's pair	0.005246	-0.037053	-0.051663

Portugal's pair	0.202091*	0.113606*	0.173636*
Slovakian pair	0.025096	-0.017324	-0.021232

*This table gives different correlation measures for each stock-euro/usd exchange rate daily return pair over the period October 16, 2009 to December 21, 2011. Total observations are 562.*Indicates statistical significance at the 1% level. **Indicates statistical significance at the 5% level. ***Indicates statistical significance at the 10% level.*

c) *Copula results*

As the copula model allows us to separate the marginal behavior from the dependence structure, the estimation of copula models is decomposed into two steps: the first for the marginals and the second for the copulas. We employ the VAR-GARCH model for the marginal distributions of each stock index return and exchange rate return series. For the Joint model, we employ copulas with different dependence structure.

i. *Results of the marginal models*

Our objective is to examine both own conditional volatility and shocks and conditional cross-market volatility transmission and shocks between the Eurozone stock returns and the foreign exchange rate returns. For that, we use the Euro Stoxx 50[2] stock index for Eurozone (EMU) stocks and the EUR_USD returns for the foreign exchange market. We experiment on GARCH terms up to p=1 and q=1. The optimal lag order for the VAR model is selected using the AIC and SIC information criteria. The estimation of the bivariate VAR (1)-GARCH (1, 1) for the two sub-period, is presented in table 5.

Table 5 : Estimation of marginal models

Variables	EMU		EUR_USD	
Meanequation	Pre-crisis	Post-crisis	Pre-crisis	Post-crisis
c	0.008778 (0.7207)	0.010827 (0.6136)	-0.007896 (0.5634)	0.017586** (0.0367)
AR(1)	-0.796434* (0.0000)	-0.772413* (0.0000)	-0.570339 (0.7914)	-0.922066* (0.0000)
Variance equation				
c	0.449347* (0.0000)	0.002431 (0.5677)	0.159475* (0.0000)	-6.39E^{-05} (0.7902)
$\boldsymbol{\varepsilon^2_{EMU}(t-1)}$	0.174233* (0.0000)	0.119697* (0.0002)	-0.000154 (0.9617)	0.045474* (0.0000)
$\boldsymbol{\varepsilon^2_{FX}(t-1)}$	0.071939** (0.0424)	0.088273*** (0.0116)	-0.010155 (0.5691)	0.949245* (0.0000)
$\boldsymbol{h_{EMU}}$(t-1)	0.807429* (0.0000)	0.795420* (0.0000)	0.033828 (0.3117)	0.000948 (0.4297)
$\boldsymbol{h_{FX}}$(t-1)	-4.636284* (0.0000)	0.088273*** (0.0116)	-0.894132* (0.0000)	0.003578** (0.0387)

Notes: $\varepsilon_j^2(t-1)$ *represents the past unconditional shocks of the* j^{th} *market in the short run, or news.*h_j *(t-1) denotes the past conditional volatility dependency. J= EMU, FX. *, **, ***indicate statistical significance level at the 1%, 5% and 10%.*

We will discuss the empirical results of bivariate VAR(1)-GARCH(1,11) models in terms of own volatility and shock dependence, cross market volatility and shock spillover for the Eurozone stock index and the FX rate, both for the pre-crisis and the post-crisis. During the pre-crisis period and for the EMU, the sensitivity to past own conditional volatility and cross market volatility transmission are significant at the level of 1%, showing that future volatility can be predicted by both the past own conditional volatility in the long run and the cross market volatility spillover. We found the same result for the own shocks or news and cross market shock transmission, indicating a short run persistence. However, the effect of past volatilities is much bigger than the effect of past shocks. This implies that fundamentals matter more than news.

Considering now the FX rate, only the past own volatility is significant but has a negative coefficient, displaying that own shocks and cross market volatility transmission and shocks cannot be used to predict either the future volatility in the long run and the short run persistence. After the occurrence of the Greek crisis, the behavior of these markets changes considerably. Indeed, the cross market volatility and shocks remains significant for the EMU stocks but their persistence diverge. The results show the effect of past shocks on the Eurozone (EMU) become bigger after the crisis, in contrast with the past own shocks effects', showing that news coming from the FX market affect more returns dynamics than past own EMU news. Moreover, cross shocks (or spillover) are more widespread inter-markets after the crisis. However, for the FX market, both own shocks and cross shocks become significant at different level and have a positive effect in the short run. This finding show that past own shocks and shock spillover can be used in predicting future shocks or new. Besides, the foreign exchange market becomes more

[2] Euro Stoxx 50 which is a stock index of Eurozone stocks. This index represents 50 of the largest companies in the Eurozone based on market capitalization and it is reconstituted at the end of each month of August. The Euro Stoxx stock index includes 50blue chip stocks across 12 Eurozone countries.

sensitive to past shocks related to changes in news or noise than fundamentals.

ii. *Results of the joint copula models*

We now present results from our copula estimation. We consider five multivariate copulas, the multivariate normal, multivariate Student-t, multivariate Gumbel, multivariate Clayton and the multivariate Frank. We first discuss the dependence structure using information criteria for European stock markets and exchange rates. Table 6 report results from AIC, SIC and HQIC information criteria.

Table 6 : Comparing dependence structures using information criteria

Models	SIC	AIC	HQIC
Panel A: Pre-crisis			
Clayton	-1266.40	-1270.93	-1269.18
Gumbel	-1093.80	-1098.33	-1096.58
Normal	-6894.37	-7500.95	-7320.14
Student-t	**-7450.90**	**-8060.71**	**-7879.46**
Frank	-972.22	-976.75	-975.00
Panel B: Post-crisis	SIC	AIC	HQIC
Clayton	-1144.87	-1149.20	-1147.51
Frank	-888.76	-893.08	-891.40
Gumbel	-1001.04	-1005.36	-1003.68
Normal	-6033.35	-6580.57	-6437.33
Student-t	**-6230.29**	**-6780.04**	**-6636.91**

Notes: AIC, SIC and HQIC are the average Akaike, Schwarz and Hannan-Quinn information criteria. These criteria were chosen to select the appropriate multivariate copula to model the dependence between daily stock-exchange market returns.

For the pre-crisis period, the best model which has lowest AIC, SIC and HQIC is the multivariate Student-t copula, with an average AIC of -8060.71, a SIC of -7450.90 and a HQIC of -7879.46 across countries, closely followed by the multivariate Gaussian copula. In the post-crisis period, the lowest AIC of -6780.04 corresponds to the Student-t copula, followed closely by the Gaussian model. The same results for the SIC and the HQIC information criteria. Thus, according to AIC, SIC and HQIC, the best fitting copula is the Student-t with symmetric tail dependence for the two sub-periods.

To better assess the degree as well as the dependence structure in the euro area, we will examine the relationship between each pair of stock-FX return separately, for the two sub period.

Table 7.A bellow, reports parameters estimates of bivariate copulas for each pair, before the occurrence of the financial Greek crisis. We note that the parameters θ and ρ measure the degree of dependence between returns and DoF is the degree of freedom in the Student-t copula.

Table 7.A : Estimation of copula parameters for the pre-crisis period

Pairs	Copula models	Parameters			Information criteria		
		ρ	DoF	θ	SIC	AIC	HQIC
France	Student-t	0.1871			-32.08	-41.14	-37.65
German	Student-t	0.1997	6		-34.16	-43.22	-39.72
Ostrich	Student-t	0.2388	5		-51.96	-61.02	-57.52
Belgium	Student-t	0.1347	5		-24.18	-33.24	-29.75
Netherland	Student-t	0.1882	5		-31.60	-40.65	-37.16
Athens	Student-t	0.2102	4		-47.92	-56.98	-53.48
Malta	Gaussian	-0.001325			11.17	2.11	5.60
Slovakia	Student-t	-0.005494	12		9.37	0.31	3.80
Cyprus	Gaussian	0.01002			6.18	1.65	3.40
Spain	Student-t	0.1805	5		-33.39	-42.45	-38.95
Ireland	Student-t	0.1085	4		-33.60	-42.66	-39.17
Luxemburg	Gumbel			1.026	13.28	4.22	7.71
Italy	Student-t	0.07914	4		-20.55	-29.61	-26.12
Finland	Student-t	0.2297	5		-47.34	56.39	52.90
Estonie	Student-t	0.09449	6		-7.96	-17.02	-13.53
Portugal	Student-t	0.003059	7		3.68	-5.38	-1.88
Slovenia	Gaussian	-0.001467			16.26	7.20	10.69

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For all pairs, the dependence parameters; the correlation coefficient ρ in both Gaussian and Student-t copulas, the degree of freedom DoF in the Student-t copula and the asymmetric dependence parameter θ in the Clayton, Gumbel and Frank copulas are positive with the expect for Malta, Slovakia and Slovenia in the pre-crisis period. The correlation coefficient ρ from the Gaussian or Student-t copula is close to the usual correlation coefficient. The DoF of the Student-t copulas are from 4 to 12, indicating the presence of extreme co-movements and tail dependence. The tail dependence parameter θ for pre-crisis period is 1.026 for the Luxemburg-foreign exchange rate pair. Thus, we can conclude that only the LUX/EUR_USD pair has asymmetric tail dependence. All the other stock market returns have elliptical symmetric dependence structure (the case of the Gaussian or the Student-t copulas) with the foreign exchange rate.

In order to appreciate both, the dependence structure and the degree of this dependence, after the Greek crisis; we estimate the copula parameters in the post-crisis period.

Table 7.B : Estimation of copula parameters for the post-crisis period

Pairs	Copula models	Parameters			Information criteria		
		ρ	DoF	ϴ	SIC	AIC	HQIC
France	Gumbel			1.36	-85.73	-94.37	-91.01
German	Student-t	0.3699	7		-73.82	-82.46	-79.10
Ostrich	Gumbel			1.331	-80.20	-88.84	-85.48
Belgium	Student-t	0.353	7		-70.48	-79.12	-75.76
Netherland	Gumbel			1.317	-67.56	-76.20	-72.84
Athens	Gaussian	0.3599			-69.99	-74.32	-72.63
Malta	Student-t	0.006634	40		13.06	4.42	7.78
Slovakia	Clayton			0.02788	13.24	4.60	7.96
Cyprus	Gaussian	-0.07477			2.62	1.70	0.02
Spain	Gaussian	0.4277			-98.60	-102.92	-
Ireland	Clayton			0.471	-38.85	-47.49	-44.13
Luxemburg	Gaussian	-0.05397			7.21	2.89	4.75
Italy	Gumbel			1.139	-20.59	-29.23	-25.87
Finland	Student-t	0.3576	8		-68.87	-77.51	-74.15
Estonie	Gaussian	0.01011			-6.05	-1.73	-3.41
Portugal	Clayton			0.2614	-20.45	-29.09	-25.73
Slovenia	Gaussian	0.06729			3.57	-0.76	0.93

For all pairs, the dependence parameters; the correlation coefficient ρ in both Gaussian and Student-t copulas, the degree of freedom DoF in the Student-t copula and the asymmetric dependence parameter θ in the Clayton, Gumbel and Frank copulas are positive, expect for Cyprus and Luxemburg.

The Spain return has the highest correlation coefficient with $\rho = 0.4277$.The DoF of the Student-t copulas are from 7 to 40, indicating the presence of strongly extreme co-movements and tail dependence. The tail dependence parameter θ for post crisis period, are from 0.02788 to 1.36. The French pair has the highest tail dependence after the crisis, followed by the Ostrich pair and the Netherland pair. Moreover, the dependence structure between each stock index returns and exchange rate returns is largely changed from a symmetric structure with or not symmetric tail dependence to an asymmetric structure with non-zero and asymmetric upper and lower tail dependence. From our results, we find The Gumbel copula which is limited to the description of a positive dependence structure. Thus, it allows only positive dependence structures or upper tail dependence, for which the parameter belongs to the interval $[1,+\infty)$.We find also the Clayton copula which possesses similar properties to the Gumbel copula. Consequently, the degree of the dependence varies when the financial Greek crisis occurs. Indeed, as we see in tables above, it increased after the crisis, expect of Cyprus which remains symmetric but with zero tail dependence. The degree of the dependence becomes weaker and moves from a positive to a negative one.

Our findings may have important implications in the risk management. First, symmetric dependence structure with zero tail dependence can specify different levels of correlation between the marginals; however, it must possess radial symmetry which doesn't allow to extreme values correlation. Thus, in this case, the dependence has the linear correlation coefficient as measure of dependence. Second, asymmetric dependence structure can have upper tail dependence, lower tail dependence, or both; as such, they can better describe the reality of the behavior of financial markets. Additionally, it indicates the potential of simultaneous extreme events in both the stock and foreign exchange market. This property of dependence structure is important to international investors who invest in foreign stock markets.

IV. Conclusion

This paper examines the dynamics relationship between foreign exchange and stock markets in the Economic European Market, after the occurrence of the Greek crisis, using daily data from February 2007 to December 2011. Based on the VAR(1)-GARCH(1,1) model, the results show that past own volatilities matter more than past shocks (news) and there exist moderate cross market volatility transmission and shocks between the markets, indicating that the past innovation in stock market have great effect on future volatility in foreign exchange market and vice versa.

Copula models are used to specify the dependence structure and to examine the degree of the dependence between these two financial markets when the Greek crisis takes place. We employ five multivariate copulas; the multivariate normal, multivariate Student-t, multivariate Gumbel, multivariate Clayton and the multivariate Frank to directly model the underlying dependence structure. We find that, during the pre-crisis period, the major of stock-foreign exchange market returns have elliptical symmetric dependence structure. However, the degree of the dependence become stronger when the financial Greek crisis occurs, presenting asymmetric upper and lower tail dependence between the two financial markets expect of Cyprus which remains symmetric but with zero tail dependence.

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