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Dynamics of global stock market correlations: the VIX and attention allocation

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ABSTRACT

This paper investigates the dynamics of international stock return correlations between the U.S., the U.K., Germany and France. Estimated correlations are modeled in an ARDL framework to evaluate how the market-wide uncertainty in the U.S. affects international stock market comovements. Results show that a shock to the VIX leads to increases in cross-country correlations in the following week and that the correlations tend to decline in the second week that follows the shock. The revealed time pattern of the effect of the VIX may be explained in a behavioral framework through investors' attention reallocation mechanism.

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Dynamic conditional correlations; return comovements; investor attention; VIX index

1. Introduction

International stock market comovement has been a key topic in finance. Empirical studies on cross-country correlations have gained importance with financial globalization as they have crucial implications for international portfolio diversification. It is now well known that return volatilities and correlations increase during turbulent periods (Ang & Bekaert, 2002). Early research on contagion and spillovers are reviewed in Karolyi and Stulz (2003) and Dungey, Fry, Gonzalez-Hermosillo, and Martin (2005). Following the global financial crisis in 2007–2009, scholarly studies have focused on analyzing the mechanisms through which the instability in the U.S. spread to other financial markets. It has been argued that a global financial cycle leads to synchronized international capital flows and that the U.S. monetary policy is the driving force behind this cycle (Rey, 2013). A cut in the Fed Funds rate induces international capital flows from the U.S. and gives rise to rapid credit growth in recipient economies. Lower interest rates also favor risk-taking behavior by the financial sector and therefore amplifies this credit channel for monetary policy transmission (Bruno & Shin, 2015). Passari and Rey (2015) suggest that the effective risk appetite of investors and realized risk levels of globally traded assets are the two factors that broadly determine the pace and direction of international capital flows. Bekaert, Hoerova, and Lo Duca (2013) find that the VIX, the U.S. implied volatility index that reflects both market risk aversion and expected stock market volatility, is affected to a large extent by the U.S. monetary policy stance. Through an extensive empirical research, Miranda-Agrippino and Rey (2020) reveal that a single

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common global factor accounts for a very important part of the variations in the price of risky assets and that this common global factor is closely related to implied volatility indices. Connolly, Stivers, and Sun (2007) show that cross-country stock return comovements tend to be stronger following high implied volatility days.

Being the biggest economy, the U.S. market has always drawn investors' attention. It is empirically shown that investors allocate more attention to the markets that are going through high-volatility periods especially when these markets are hit by an unanticipated crisis and that this attention reallocation mechanism leads to financial contagion (Mondria & Quintana-Domeque, 2013). Attention reallocation mechanism is employed also to explain increases in individual stock return correlations. Peng, Xiong, and Bollerslev (2007) and Ceylan (2015) find that stock return correlations increase after a shock to market-wide uncertainty for the U.S. and French stock markets respectively. Investors shift their limited attention to resolve the market-wide uncertainty initially at the expense of stock-specific factors. As a result, individual stocks tend to be more correlated, and these correlations start to decrease only after investors divert their attention back to processing stock-specific information.

Recent empirical findings show that both the individual and institutional investors shift their focus following changes in economic conditions. Based on a large data set on investors' logins to 401(k) accounts, Sicherman, Loewenstein, Seppi, and Utkus (2016) find that investor attention is negatively correlated with the VIX. Investors allocate less attention to their portfolios when the VIX goes up. Similarly, based on a brokerage account data set, Gargano and Rossi (2018) show that individual investors with riskier portfolios pay less attention to stock-specific information. Kacperczyk, Van Nieuwerburgh, and Veldkamp (2014, 2016) reveal that fund managers focus on stock picking during economic booms and market timing during recessions. Dong (2020) suggests that institutional investors' trading decisions are prone to be affected by market noise during periods of extreme market sentiment. In such periods, investors allocate additional attention to market noise, and this results in trading decisions that lead to stock mispricing.

This paper investigates whether the above mentioned attention reallocation mechanism may help to explain the observed patterns of international stock return correlations. Conditional return correlations are first estimated for four stock market indices, S&P 500 for U.S., FTSE 100 for U.K., CAC 40 for France and DAX 30 for Germany for the period from 2000 to 2020 through Dynamic Conditional Correlations-Generalized Autoregressive Conditional Heteroscedasticity (DCC-GARCH) model that is developed by Engle (2002). These bivariate conditional correlations are then put in Autoregressive Distributed Lag (ARDL) models in which multiple lags of the VIX index are employed as exogenous regressors. This methodological framework allows one to identify the time pattern of the effect of VIX on cross-country stock return correlations. The empirical results support the hypothesis that the attention reallocation mechanism may have an important role in explaining international stock return comovements. A shock to the VIX leads to increases in correlations between the U.S. and each of the European stock markets in the following week as investors focus on this global uncertainty. A very large part of the shock is absorbed and thus correlations decrease in the second following the shock. A similar time pattern is also observed concerning the correlations between the European stock market indices.

The paper is structured as it follows: the data and empirical models used in the estimations are presented in Section 2, empirical results are discussed in Section 3, and the conclusion is presented in Section 4.

2. Empirical methodology and data

2.1. Conditional correlations

Early studies compare unconditional correlations computed for crisis and no-crisis subsamples to find evidence for contagion (King & Wadhvani, 1990; Lee & Kim, 1993). Forbes and Rigobon (2002) argue that these results are biased as they are based on unconditional correlations that do not account for heteroscedasticity. DCC-GARCH model overcomes this heteroscedasticity problem and provides conditional estimates for correlations.

Denote by Y_t the vector containing bivariate asset return series, and by F_t the information set to time t . Then,

$Y_t|VF_{t-1} = \epsilon_t MD(0, H_t)$ where ϵ_t is a vector of innovations following a multivariate density function, MD , with mean zero and a dynamic conditional covariance matrix, H_t . Note that the return series Y_t should be modeled based on F_{t-1} for the innovations to have no serial correlation.

Engle (2002) decomposed the conditional covariance matrix into the product of dynamic conditional standard deviations and dynamic conditional correlations:

$$H_t = D_t R_t D_t$$

where D_t is a diagonal matrix of conditional standard deviations, $\sigma_{1,t}, \sigma_{2,t}$, each following a univariate GARCH(r,s) process:

$$\sigma_t^2 = \omega + \sum_{k=1}^r \alpha_k \epsilon_{t-k}^2 + \sum_{l=1}^s \beta_l \sigma_{t-l}^2$$

where ω is the constant, α and β are the ARCH and GARCH coefficients, respectively.

DCC framework focuses on modeling the evolution of R_t , the dynamic conditional correlation matrix that satisfies the following conditions:

$$R_t = \text{diag}\{Q\}_t^{-0.5} Q_t \text{diag}\{Q\}_t^{-0.5}$$

where for a DCC(m,n) model Q_t is given as follows:

$$Q_t = (1 - \sum_{i=1}^m \tau_i - \sum_{j=1}^n \zeta_j) S + \sum_{i=1}^m \tau_i \eta_{t-1} \eta_{t-1}^T + \sum_{j=1}^n \zeta_j Q_{t-1}$$

where S is the unconditional covariance matrix of the standardized residuals (η), τ and ζ are non-negative parameters of interest that determine the variations conditional correlations.

2.2. ARDL models

ARDL models are employed to investigate the dynamic relationship between the estimated conditional correlations and the VIX. An ARDL(k, l) model can be represented in its extensive form as follows:

$$\rho_t = c + \sum_{i=1}^k a_i \rho_{t-i} + \sum_{j=0}^l b_j VIX_{t-j} + u_t$$

where ρ_t represent dynamic conditional correlations and u_t is white noise. In this model the VIX is reasonably assumed as an exogenous variable. To avoid spurious regression, the model may need to be altered depending on whether the dependent and exogenous variables are stationary or not. After checking for stationarity, model lag orders are determined based on both statistical significances of model coefficients and Bayesian information criterion. Additional care should be taken to ensure that model residuals exhibit no serial correlation.

2.3. Data

For this study, dynamic conditional correlations are computed using weekly logarithmic index return data for four major stock markets: S&P 500 (U.S.), FTSE 100 (U.K.), CAC 40 (France) and DAX 30 (Germany) for the period from January2000 to May2020. For empirical studies that cover several markets, the use of weekly index return data instead of daily returns helps to avoid nonsynchronous trading problem that may stem from differences in market holiday periods in different countries. Table 1 presents the summary statistics for the weekly log returns of these four stock market indices.

Chicago Board of Options Exchange publishes the VIX, implied volatility series that are computed based on S&P 500 index options for near and next-term maturities. VIX is an effective measure for one-month ahead risk-neutral expectation of the integrated volatility. It provides information on the expected volatility of the underlying stock index returns (Christensen & Prabhala, 1998), and contains also the volatility risk premia which may serve as a proxy for market-wide risk aversion (Bakshi & Kapadia, 2003; Bollerslev, Tauchen, & Zhou, 2009). Variations in VIX capture crisis and tranquil periods for the U.S. market over the estimation period as shown in Figure 1. That is why the VIX is also a good candidate for explaining global stock market comovements. Summary statistics for the VIX are provided in Table 3.

Table 1. Summary statistics for index returns.

Series	Min	Max	Mean	Median	Std. Dev.	Skewness	Kurtosis
S&P 500	-20.084	11.424	0.067	0.203	2.513	-0.947	7.863
FTSE 100	-23.617	12.584	-0.009	0.191	2.447	-1.378	13.45
CAC 40	-25.05	12.432	-0.019	0.234	3.016	-1.168	8.228
DAX 30	-24.347	14.942	0.045	0.394	3.239	-0.904	6.700



Figure 1. The VIX index.

3. Estimation results

DCC-GARCH estimation results for bilateral stock market correlations are given in Table 2. For each estimation DCC(1; 1)-GARCH(1; 1) model is found to be appropriate based on BIC and significance of model coefficients. The first six coefficients concern conditional mean and variance equations of the GARCH models applied to the corresponding stock markets. τ and ζ are the DCC parameters that determine the variations in conditional correlations.

A closer look to DCC parameters reveals that the dynamic correlations between the U.S. and each European stock market show higher persistence: the respective sums of DCC parameters are close to one. Correlations between the European markets present

Table 2. DCC estimation results.

U.S. – U.K.		U.S. – FRANCE		U.S. – GERMANY	
Parameter	Value	Parameter	Value	Parameter	Value
$\mu_{U.S.}$	0.2277**	$\mu_{U.S.}$	0.2277**	$\mu_{U.S.}$	0.2277**
$\omega_{U.S.}$	0.3248**	$\omega_{U.S.}$	0.3248**	$\omega_{U.S.}$	0.3248**
$a_{U.S.}$	0.2578**	$a_{U.S.}$	0.2578**	$a_{U.S.}$	0.2578**
$\beta_{U.S.}$	0.7110**	$\beta_{U.S.}$	0.7110**	$\beta_{U.S.}$	0.7110**
$\mu_{U.K.}$	0.1193*	μ_{FR}	0.1543*	$\mu_{GER.}$	0.2823**
$\omega_{U.K.}$	0.3360**	ω_{FR}	0.3372*	$\omega_{GER.}$	0.8950**
$a_{U.K.}$	0.2155**	a_{FR}	0.1646**	$a_{GER.}$	0.2657*
$\beta_{U.K.}$	0.7487**	β_{FR}	0.8117**	$\beta_{GER.}$	0.6699**
τ	0.0316**	τ	0.0235*	τ	0.0403**
ζ	0.9539**	ζ	0.9623**	ζ	0.9228**
Log-lik.	-4102.47	Log-lik.	-4327.89	Log-lik.	-4413.04
U.K. – FRANCE		U.K. – GERMANY		FRANCE – GERMANY	
Parameter	Value	Parameter	Value	Parameter	Value
$\mu_{U.K.}$	0.1193*	$\mu_{U.K.}$	0.1193*	μ_{FR}	0.1543*
$\omega_{U.K.}$	0.3360**	$\omega_{U.K.}$	0.3360**	ω_{FR}	0.3372*
$a_{U.K.}$	0.2155**	$a_{U.K.}$	0.2155**	a_{FR}	0.1646**
$\beta_{U.K.}$	0.7487**	$\beta_{U.K.}$	0.7487**	β_{FR}	0.8117**
μ_{FR}	0.1543*	$\mu_{GER.}$	0.2823**	$\mu_{GER.}$	0.2823**
ω_{FR}	0.3372*	$\omega_{GER.}$	0.8950**	$\omega_{GER.}$	0.8950**
a_{FR}	0.1646**	$a_{GER.}$	0.2657*	$a_{GER.}$	0.2657*
β_{FR}	0.8117**	$\beta_{GER.}$	0.6699**	$\beta_{GER.}$	0.6699**
τ	0.0620**	τ	0.1179**	τ	0.0605*
ζ	0.9076**	ζ	0.7690**	ζ	0.8708**
Log-lik.	-4119.73	Log-lik.	-4357.3	Log-lik.	-4206.04

μ is the constant of the return equation, ω is the constant of the volatility equation; a and β are the ARCH and GARCH coefficients from univariate GARCH models. τ and ζ are the DCC parameters. ** and * indicate statistical significance at the 1% and 5% levels, respectively.

Table 3. Summary statics and unit-root test results for ARDL model variables.

Series	Min	Max	Mean	Median	Std. Dev.	Skewness	Kurtosis	DF-GLS
US-UK	0.417	0.877	0.748	0.765	0.083	-0.771	0.121	-2.813
US-FR	0.621	0.898	0.767	0.775	0.056	-0.446	-0.552	-2.856
US-GER	0.537	0.894	0.762	0.773	0.066	-0.851	0.396	-4.114
UK-FR	0.446	0.969	0.833	0.852	0.086	-1.683	3.780	-4.965
UK-GER	0.308	0.967	0.786	0.803	0.090	-1.410	3.151	-5.747
FR-GER	0.759	0.976	0.906	0.912	0.029	-1.415	3.345	-4.572
VIX	9.140	79.130	19.549	17.150	8.949	2.284	7.949	-3.840

The last column provides the DF-GLS test statistics. Critical values for the test are -2,57, -1,94 and -1,62 for the 1%, 5% and 10% significance levels, respectively.

relatively faster mean reversion driven by the lower DCC parameter sums. This difference can be seen also in Figure 2 where bilateral dynamic correlations are plotted on separate graphics.

Average correlation levels between the U.S. and European stock markets are lower than those between the European markets. Correlations between the French and German stock markets are higher and more stable than those between the U.K. and France and the U.K. and Germany. These preliminary observations seem to reflect the fundamental features of international stock market integration: The U.K. has been a part of the European Union for almost the whole estimation period, but differently from Germany and France, the U.K. has not adopted the Euro.

Although these depicted correlations show differences in terms of mean reversion behaviors, it can be observed that they all follow generally similar patterns. For instance, all cross-country correlations tend to increase following the dot-com bubble burst, 9/11

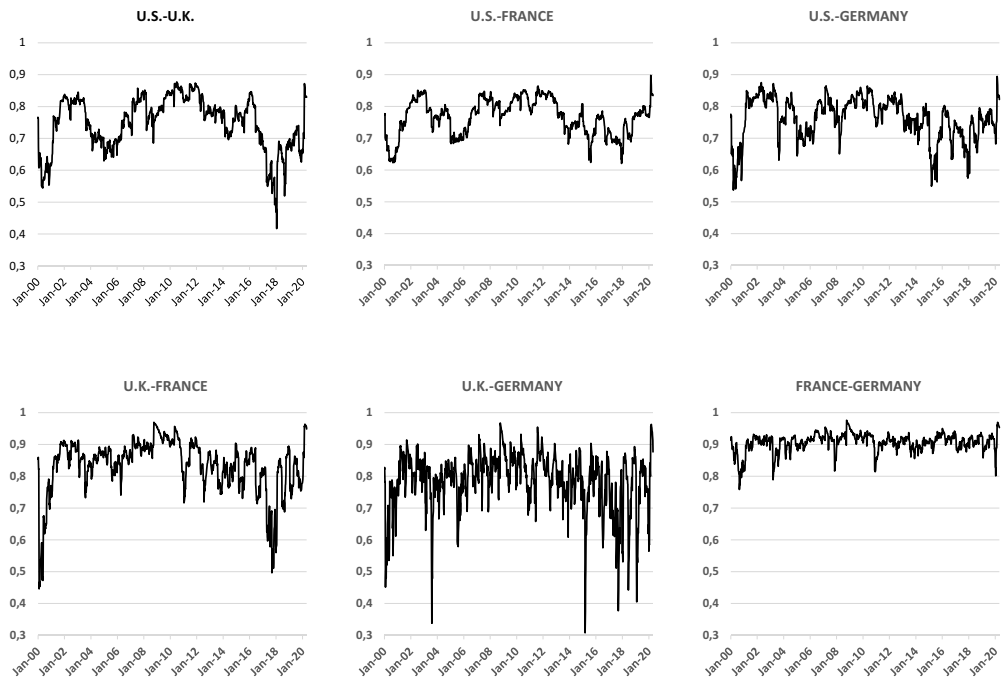


Figure 2. Dynamic conditional correlations.

Table 4. ARDL model estimation results.

Series	c	a	b ₁	b ₂	B-G
US-UK	0.01507	0.97555	0.00122	-0.00105	0.505
US-FR	0.01502	0.97862	0.00066	-0.00059	0.689
US-GER	0.03307	0.95216	0.00119	-0.00102	0.685
UK-FR	0.03467	0.95277	0.00150	-0.00126	0.497
UK-GER	0.11042	0.84276	0.00265	-0.00197	0.315
FR-GER	0.06841	0.92270	0.00080	-0.00071	0.802

c is the intercept, a is the AR(1) coefficient, b₁ and b₂ are the coefficients for the first and second lags of the VIX, respectively. All coefficients are significant at the 1% level. The last column provides the p-values from the Breusch-Godfrey test results.

attacks, Lehman Brothers' bankruptcy, and ongoing Covid-19 pandemic. On the other hand, common periods of lower correlations correspond to tranquil market conditions during which the VIX is also low. This makes the VIX a potential predictor for the dynamics of the cross-country correlations. Thus, the estimated ARDL models include the conditional stock market correlations and the VIX. Summary statistics for these variables are provided in Table 3. To avoid spurious regression problem, model variables should initially be tested for stationarity. Elliott, Rothenberg, and Stock (1996) proposed a modified Dickey-Fuller test (known as the DF-GLS test) which has been shown to have greater power against the alternative hypothesis of stationarity when compared to the other versions of Dickey-Fuller tests. Test statistics for each variable are also provided in Table 3. Critical values for the test are -2,57, -1,94 and -1,62 for the 1%, 5% and 10% significance levels, respectively. The test results support rejecting the null hypothesis unit-root for all variables at the 1% significance level.

For each correlation series, ARDL models are set based on both statistical significances of model coefficients and BIC. All models include the first lag of the dependent variable and the first two lags of the exogenous variable. Estimation results are presented in Table 4. Additional care should be taken to ensure that model residuals exhibit no serial correlation. To assess the validity of the model, residuals are checked for serial correlation by using the Breusch-Godfrey test. Resulting p-values are also given in Table 4. Results show that there is no serial correlation problem for the estimated models.

Correlations between the U.S. stock market and each of the European markets increase following an increase in market-wide uncertainty in the U.S. which is represented by a rise in the VIX. This increase in the VIX grabs the attention of investors, and investors focus on resolving this global uncertainty factor. Correlations tend to decline towards their initial values in the second week that follows the shock as investors manage to process this shock until then. This process also affects the correlations between the European stock market indices. Consecutive increases in the VIX during the crisis periods lead to long periods of increasing trends in cross-country correlations.

4. Conclusion

This paper has investigated the dynamics of international stock return correlations. Cross-country correlations among the U.S., the U.K., Germany and France have been initially estimated by using DCC models. The estimated conditional correlations have then been modeled in an ARDL framework in which multiple lags of the VIX index are

employed as exogenous regressors to evaluate how the market-wide uncertainty in the U.S. affects international stock market comovements. Estimation results have shown that a positive shock to the VIX leads to increases in cross-country correlations in the following week and that the correlations tend to decline through their initial values in the second week that follows the shock.

These findings support the mass literature which claim that correlations increase in high volatility periods. The role of the VIX is emphasized as a short-run predictor for the dynamics of cross-country return correlations. It is shown that the revealed time pattern of the effect of the VIX may possibly be explained in a behavioral framework through investors' attention reallocation mechanism. Investors shift their limited attention to initially resolve the increased global uncertainty at the expense of country-specific or stock-specific factors. As a result, international stock market comovements tend to increase until investors resolve this global uncertainty factor and divert their attention back to processing country-specific information.

Disclosure statement

No potential conflict of interest was reported by the author.

Notes on contributor

Özcan Ceylan is Assistant Professor at the School of Applied Sciences at Özyeğin University in Turkey. He received his PhD in Economics from Université Paris Ouest Nanterre La Défense in 2011. His research interests cover behavioral finance, high frequency data econometrics, asset pricing and international finance.

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Data availability

The data that support the findings of this study are available from the corresponding author, [Ö. C.] upon reasonable request.

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