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ASSESSING THE INTENSITY OF US-LATIN AMERICAN MARKET COMOVEMENTS AND CONTAGION EFFECTS IN TIMES OF CRISIS

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Abstract

We investigate the comovements and contagion effects between four emerging markets in Latin America and the US stock market using two multivariate volatility GARCH-based models: the DCC-GARCH and BEKK-GARCH models. A structural change analysis is also applied to detect the changing patterns in the cross-market dynamic linkages. Our results show that the DCC-GARCH model provides better in-sample estimates than the BEKK-GARCH model. We also find evidence of time-varying market comovement, but the results are inconsistent with higher comovements between these markets in recent years. Finally, the financial contagion hypothesis associated with the Mexican crisis of 1994, the Asian crisis of 1997-1998, and the global financial crisis of 2008-2009 is not supported by our data, in almost all cases.

Keywords: market comovements, emerging Latin America, multivariate GARCH, structural change.

JEL Classification: F37; G15

1. Introduction

Studies on international stock market dynamics and comovements have recently gained ground in the finance literature. This increase of interests and motivations can be explained by various reasons, but the most relevant of all includes the search for potential benefits of portfolio diversification and the recurrence of financial crises. Indeed, stock markets all over the world have recently experienced a succession of serious crisis of different origins and effects. Just to name a few, the 1997-1998 Asian crises occurred in South Asian economies as a result of “host” short-term capital outflows and spread its severe effects to other emerging equity and commodity markets. The 2001 US recession caused by the collapse of the dot com stocks and triggered a

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push toward greater bank liquidity. Lastly, the 2007-2010 global financial crisis following the US subprime crisis and baking defaults has strongly affected financial markets of almost all countries. These crises were characterized by high financial market volatility, high risk aversion given the excessive fear and the loss of confidence of market participants, and increased correlations (comovements) which typically reduce the diversification benefits (Chan-Lau et al., 2004; Diamandis, 2009). Several studies have found some evidence of contagion effects among national stock markets during times of crises (Forbes and Rigobon, 2002; Bekaert et al., 2005; Markwat et al., 2009).

To gauge the intensity of the interdependencies between national stock markets during crisis periods in order to prevent the risks of contagion as well as to measure the potential benefits of international portfolio diversification, past empirical investigations have employed a wide variety of methods and data frequencies at both firm and country levels. The focus was mostly on the correlations as well as the return and volatility spillovers between markets around the world (Syriopoulos, 2007; Morana and Beltratti, 2008; and Gilmore *et al*., 2008). They mainly find significant comovements among international stock markets and evidence of a positive relation between correlation and volatility.

This article addresses the comovements between four major emerging markets in Latin America and the United States (US). Over the last two decades, emerging markets and Latin American emerging markets in particular have played a pivotal role in global portfolio diversification because of their high expected returns spurred by high economic growth rates and because of their low correlations with mature markets. As the market liberalization accelerates and renders emerging markets more integrated into the world financial system, one may wonder to know about their diversification benefits, and in this case about their degree of comovements with other markets. For this purpose, Choudry (1997) examine the long-term relationship between six Latin American markets and the US market, and finds evidence of a cointegration link and significant causality among these markets. Chen et al. (2002) investigate the interdependencies of six equity markets in Latin America and document that diversification benefits are limited when investing in these markets, particularly owing to their high level of comovement. By combining a vector autoregressive (VAR) model with a multivariate exponential GARCH process, Christofi and Pericli (1999) show evidence of significant cross-market linkages in five Latin American markets. Johnson and Soenen (2003) examine the cross-country comovement for eight Latin American equity markets with the US market using the Geweke (1982) measure of contemporaneous feedback between return series. They find a statistically significant linkage between eight equity markets in the Americas and the US stock market. In a more recent paper, Fujii (2005) finds evidence of the intra-causal linkages among four Latin American markets, and further demonstrates that these causal linkages are stronger during times of major financial crisis. Lahrech and Sylwester (2011) use dynamic conditional correlations to model the linkages between the US market and the same four major Latin American emerging markets, but they do not analyze the potential of structural change in the comovement series.[4]

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[4] See Worthington and Higgs (2004) and Li and Majerowaska (2007), among others, for detailed discussions on the issue of market comovement as well as return and volatility transmission among other emerging markets in Asia, and Central and Eastern Europe.

Our study joins the above literature by empirically investigating the comovement issue in the context of Latin American emerging markets. We contribute to the related literature in several aspects. First, instead of modeling the comovement by VAR and realized correlations as in past studies, which capture the causal linkages but do not permit to quantify the comovement, we directly infer the cross-market linkages from the stock data using two competing multivariate GARCH models: the Dynamic Conditional Correlation GARCH model (DCC-GARCH) and the BEKK-GARCH model. Second, we are interested in dating the structural breaks in the time-paths of the conditional correlation indices to highlight whether the cross-market comovement encompasses significant changes in nature or not. Finally, our methodology enables the investigation of the differences in stock market comovements between normal and crisis periods.

Using a dataset that covers the last important crises, our findings show that the DCC-GARCH model reproduces better the dynamics of stock market returns in Latin America than the BEKK-GARCH model. There is strong evidence of significant time-varying market linkages between Latin American and US stock markets. In addition, stock returns in the US markets significantly affect the contemporaneous dynamics of stock returns in most of the emerging Latin American markets considered. The analysis of structural changes, based on Bai and Perron (2003)'s procedure, indicates that the comovements of Latin American emerging stock markets with the US stock markets are subject to several structural breaks which generally coincide with major market events including market liberalization policies and the Asian financial crisis of 1997. Our findings do not support the hypothesis of contagion effects around the most recent financial crisis.

The rest of the article is organized as follows. Section 2 presents our empirical methodology. Section 3 presents the data used and reports the empirical results. Section 4 provides some concluding remarks.

2. Econometric Method

We consider two competing multivariate GARCH models to measure the comovement between markets: the DCC-GARCH and BEKK-GARCH models. Our analysis of comovements then relies on the time-varying correlation coefficients estimated from the multivariate model selected by information criteria.

Assume that returns from k markets are multivariate normally distributed with zero mean and conditional variance-covariance matrix H_t, the multivariate BEKK-GARCH model, which was introduced by Engle and Kroner (1995), can be written as follows

$$\begin{cases} \tilde{r}_t = \mu_t + \varepsilon_t, \quad \varepsilon_t \big| I_{t-1} \to N(0, H_t) \\ H_t \equiv CC' + A\varepsilon_{t-1}\varepsilon_{t-1}'A' + BH_{t-1}B' \end{cases} \quad \text{... (1)}$$

where $\tilde{r}_t$ is the $(k\times 1)$ vector of the returns on stock market indices; and ε_t is a $(k\times 1)$ vector of zero mean return innovations conditional on the information available at time $t-1$. A and B are $(k\times k)$ parameter matrices and C is a lower triangular parameter matrix. Let $\tilde{r}_i$ and $\tilde{r}_w$ be the rates of return on an individual emerging market and the US stock market index respectively; we further assume that stock market returns are generated by an autoregressive process such as

$\mu_{i,t} = \delta_{i0} + \delta_{i1}\tilde{r}_{i,t-1} + \delta_{i2}\tilde{r}_{w,t} + \delta_{i3}\tilde{r}_{w,t-1}$ for emerging market i

and

$\mu_{w,t} = \delta_{wo} + \delta_{w1}\tilde{r}_{w,t-1}$ for the US stock market

On the other hand, the multivariate DCC-GARCH model, which assumes the same conditional mean specification, can be specified as

$$\begin{cases} \tilde{r}_t = \mu_t + \varepsilon_t, \quad \varepsilon_t \middle| I_{t-1} \rightarrow N(0, H_t) \\ H_t \equiv D_t R_t D_t \end{cases} \qquad \text{... (2)}$$

D_t refers to a ($k \times k$) diagonal matrix with the elements on its main diagonal being the conditional standard deviations of the returns on each market in the sample, and R_t is the ($k \times k$) conditional correlation matrix. D_t and R_t are defined as follows:

$$D_t = \text{diag}(h_{1kt}^{1/2} ... h_{kkt}^{1/2}) \qquad \text{... (3)}$$

where h_{iit} is chosen to be a univariate GARCH(1,1) process;

$$R_t = (\text{diag}(Q_t))^{-1/2} Q_t (\text{diag}(Q_t))^{-1/2} \qquad \text{... (4)}$$

where $Q_t = (1-\alpha-\beta)\bar{Q} + \alpha u_{t-1} u_{t-1}^{'} + \beta Q_{t-1}$ refers to a ($k \times k$) symmetric positive definite matrix with $u_{it} = \varepsilon_{it} / \sqrt{h_{iit}}$, $\bar{Q}$ is the ($k \times k$) unconditional variance matrix of u_t, and α and β are non-negative scalar parameters satisfying $\alpha + \beta \prec 1$. The conditional correlation coefficient ρ_{ij} between two markets *i* and *j* is then expressed as

$$\rho_{ij} = \frac{(1-\alpha-\beta)\bar{q}_{ij} + \alpha u_{i,t-1} u_{j,t-1} + \beta q_{ij,t-1}}{\left((1-\alpha-\beta)\bar{q}_{ii} + \alpha u_{i,t-1}^2 + \beta q_{ii,t-1}\right)^{1/2} \left((1-\alpha-\beta)\bar{q}_{jj} + \alpha u_{j,t-1}^2 + \beta q_{jj,t-1}\right)^{1/2}} \qquad \text{... (5)}$$

In Equation (5), q_{ij} refers to the element located in the *i*th row and *j*th column of the symmetric positive definite matrix Q_t.

Overall, the set of unknown parameters of BEKK-GARCH parameterization is estimated by the quasi-maximum likelihood (QML) using the Berndt-Hall-Hall-Hausman (BHHH) optimization method. For the DCC-GARCH model, the same estimation method is used, but the estimation is carried out by using a two-stage procedure. We first estimate a univariate GARCH(1,1) model for each time series, and then employ the resulting residuals standardized by their conditional standard deviations to infer the conditional correlation estimators.

Once the best volatility model is selected, we proceed to investigate whether structural changes are present in the conditional time-series of cross-market correlations. Our motivation comes essentially from the complexity of stock market liberalizations in Latin American countries and the recurrence of financial crises that have unhinged world markets in recent years. Indeed, Latin American emerging markets have experienced significant reforms in their capital markets over the last three decades. They occurred in various periods of financial turbulence including, among others, the Mexican crisis in 1994-1995, the Brazilian crisis in 1998, and the Argentinean crisis in 2001. Both Latin American emerging and the US markets were also severely affected by the recent global financial crisis of 2007-2009. Thus the time-paths of cross-market comovements might accordingly be subjected to structural changes. The idea is that a higher degree of financial openness can strengthen the relationships between international stock markets, but the depth of serious financial crises may affect a country's economic and financial structure, which in turn leads to changes in the nature of its comovements with other countries. Since the changes in the cross-market comovements may affect the policy coordination of two or more countries as well as the actions of portfolio managers, it is opportune to examine the issue of structural changes.

Our analysis of structural change is based on the Bai and Perron (2003)'s testing procedure, which consists of determining the number and location of breaks in a linear regression framework. More precisely, suppose there are *m* breaks $(n_1,...,n_m)$ in the time-path of the dependant variable, the problem of dating structural breaks amounts to finding the breakpoints $(\tilde{n}_1,...,\tilde{n}_m)$ that minimize the objective function:

$$(\tilde{n}_1,...,\tilde{n}_m) = \operatorname{argmin}_{(n_1,...,n_m)} RSS_n(n_1,...,n_m)$$

where RSS_n is the resulting residual sum of squares based on the *m* regressions as shown by the following equation:

$$y_t = \beta x_t^T + \varepsilon_t \qquad (t = 1,...,n) \qquad ... (6)$$

In Equation (6), y_t plays the role of the estimated conditional correlation series at the time *t*, $x_t = (1, y_{t-1})^T$ is the (2×1) vector of observations of the independent variables with the first component equal to unity, β is the (2×1) vector of regression coefficients, i.e., a constant term and an autoregressive coefficient, and ε_t is assumed to be independent and identically distributed according to a normal distribution with zero mean and variance σ^2. Our structural stability test is then concerned with testing the null hypothesis of '*no structural break*' against the alternative that the regression coefficients vary over time. Empirically, we set the maximum number of optimal breaks to be 5 and run the test. Whenever the effective number of breaks is equal to 5, a higher number of breaks will be automatically chosen so that the testing procedure captures all possible breakpoints. The optimal number of breaks corresponds to the one with the lowest BIC score.

3. Data and Empirical Findings

3.1 Data and Properties

We use monthly stock market returns from four Latin American markets (Argentina, Brazil, Chile, and Mexico) and the US market over the period from February 1988 to April 2009. All the indices are obtained from MSCI Barra and expressed in US dollars to preserve homogeneity across markets and also to avoid the effects of currency risks. They are converted to return series by calculating the differences in natural log prices. The basic statistics and stochastic properties of the monthly returns are presented in Table 1.

Table 1. Descriptive statistics and stochastic properties of stock market returns

Panel A: Summary statistics					
	Argentina	*Brazil*	*Chile*	*Mexico*	*US*
Mean (% per month)	0. 979	1.125	1.011	1.296	0.489
Std-Dev. (% per month)	14.962	16.155	7.204	9.587	4.328
Excess skewness	0.365**	-1.396***	-0.654***	-1.026***	-0.817***
Excess kurtosis	3.956***	9.790***	2.843***	3.237***	1.844***
Jarque-Bera	172.011^{+++}	1101.296^{+++}	104.112^{+++}	156.148^{+++}	64.575^{+++}
Q(12)	6.421	19.366^{+}	13.089	20.647^{+}	18.233^{+}
ARCH(12)	38.731^{+++}	18.988^{+}	20.960^{++}	23.451^{++}	29.447^{+++}
Panel B: Autocorrelations					
Lag	*Argentina*	*Brazil*	*Chile*	*Mexico*	*US*
1	0.059	-0.105	0.163	0.090	0.071
2	-0.015	0.026	0.002	0.034	-0.020
3	0.001	-0.108	-0.068	0.073	0.103
4	0.057	-0.039	0.072	-0.040	0.059
5	-0.087	0.004	0.026	-0.023	0.026
6	-0.021	-0.047	-0.049	-0.114	-0.041
Panel C: Unconditional correlation matrix of stock market returns					
	Argentina	*Brazil*	*Chile*	*Mexico*	*US*
Argentina	1.000				
Brazil	0.293	1.000			
Chile	0.348	0.413	1.000		
Mexico	0.479	0.378	0.468	1.000	
US	0.336	0.383	0.467	0.568	1.000

Notes: JB is the Jarque-Bera test for normality based on skewness and kurtosis. Q(12) is the Ljung-Box test for autocorrelation of order 12. ARCH is the Engle (1982)'s test for conditional heteroscedasticity. ***, ** and * indicate significance of coefficients at the 1%, 5% and 10% respectively. $^{+++}$, $^{++}$ and $^{+}$ indicate rejection of the null hypotheses of no autocorrelation, normality and homoscedasticity at the 1%, 5% and 10% levels of significance respectively for statistical tests.

Panel A indicates that the monthly average of Latin American market returns ranges from 0.979% in Argentina to 1.296% in Mexico. Their returns are indeed consistently above those provided by the US stock market (0.489% per month). However, it is important to note that all the sample emerging markets experienced a very high level of unconditional volatility, Brazil being the most volatile market with a standard deviation of 16.155%, followed by Argentina, Mexico, and Chile. Investors should therefore be aware of the fact that some emerging markets may not be attractive in terms of risk-return tradeoff. Skewness and kurtosis coefficients are all significant at the conventional levels. The Jarque-Bera test for normality based on the third and fourth moments strongly rejects the hypothesis of normally distributed returns. These facts support our decision to use the quasi-maximum likelihood (QML) approach of Bollerslev and Wooldridge (1992) to estimate the empirical model. We also performed the Engle (1982) test for conditional heteroscedasticity and find that the null hypothesis of no ARCH effects is rejected for all of the stock markets. The null hypothesis of no autocorrelation of order 12 is rejected for Brazil, Mexico, and the US. The first-order autocorrelation, reported in Panel B, is significant for Chile. Altogether, this suggests that a final auto-regressive correction is needed in the mean equations.

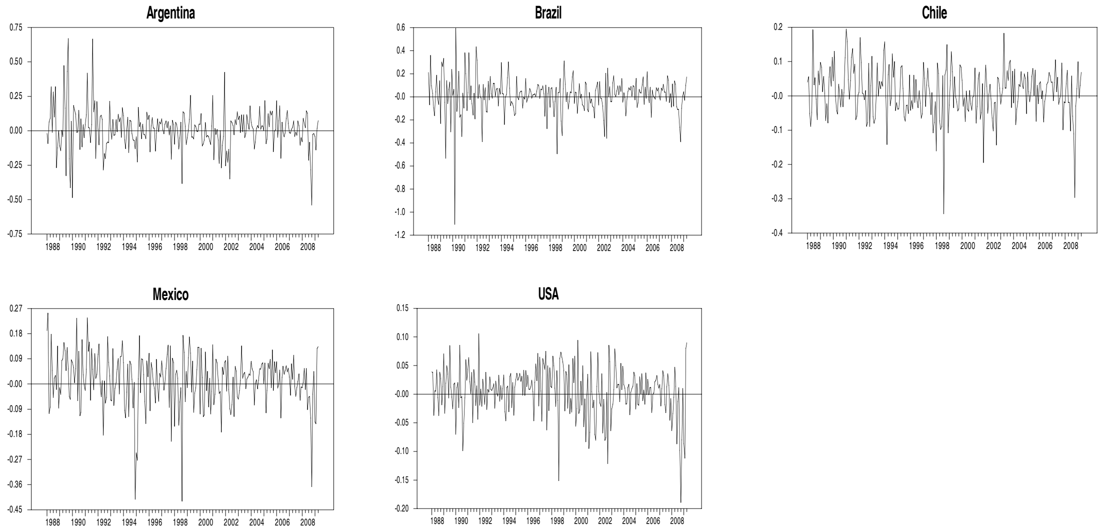

Figure 1. Dynamic patterns of monthly stock market returns

Figure 1 shows the time-variations in return series from the sample stock markets. Unsurprisingly, these series are quite unstable and testify to periods of high volatility, especially during times of crisis. If we look closely at each market, we see that the Mexican stock market was particularly sensitive to the Tequila debt crisis of 1994-1995, and that the stock markets in Argentina and Brazil reacted strongly to their market-opening events during the years from 1989 to 1993 (Bekaert and Harvey, 2000). All the markets experienced sharp declines in returns at the time of the Asian financial crisis of 1997-1998 and the global financial crisis of 2007-2008, except for Brazil.

Panel C reports the unconditional correlations among markets. As expected, they are all positive and range from 0.293 (Brazil-Argentina) to 0.568 (Mexico-US). The important linkages between Mexico and the US can be broadly explained by the fact that both markets are members of the trilateral trade block in North America (NAFTA). Within the Latin American region, the highest unconditional correlation is between Argentina and Mexico (0.479). The values of the unconditional correlations are quite low, suggesting that the diversification benefits from investing in these emerging markets still remain substantial.

3.2 Estimation Results of Multivariate GARCH Models

Table 2 contains parameter estimates and a number of diagnostic tests for the BEKK-GARCH model and Table 3 reports those for the DCC-GARCH model.

Table 2. Estimation results of the BEKK-GARCH model

Panel A – parameter estimates of the mean equations					
	Argentina	*Brazil*	*Chile*	*Mexico*	*US*
δ_0	0.017*	-0.067***	0.024***	0.062***	0.010***
	(0.009)	(0.015)	(0.006)	(0.013)	(0.002)
δ_1 (1st lag of local market returns)	-0.004	0.035	0.062	0.041	-----
	(0.052)	(0.648)	(0.055)	(0.056)	
δ_2 (current lag of the US market returns)	0.044	9.250***	-0.528	-3.864***	-----
	(0.526)	(0.648)	(0.386)	(0.572)	
δ_3 (1st lag of the US market returns)	0.305*	-0.333	0.052	0.309	0.039
	(0.178)	(0.436)	(0.135)	(0.306)	(0.054)
Panel B - parameter estimates of the variance processes					
	Argentina	*Brazil*	*Chile*	*Mexico*	*US*
$C_{Argentina,i}$	0.018				
	(0.012)				
$C_{Brazil,i}$	-0.006	0.088***			
	(0.061)	(0.020)			
$C_{Chile,i}$	0.005	-0.005	0.0001		
	(0.015)	(0.005)	(0.010)		
$C_{Mexico,i}$	0.020	-0.023*	0.0002	-0.002E-3	
	(0.042)	(0.012)	(0.019)	(0.007)	
$C_{USA,i}$	0.002	-0.009***	0.001E-2	0.028E-5	0.002E-5
	(0.008)	(0.002)	(0.001)	(0.001)	(0.001)
$A_{Argentina,i}$	0.111**	-0.074	0.008	-0.063	-0.008
	(0.045)	(0.075)	(0.030)	(0.068)	(0.010)
$A_{Brazil,i}$	-0.162***	-0.072	0.055	0.208**	0.029**
	(0.043)	(0.122)	(0.038)	(0.088)	(0.014)
$A_{Chile,i}$	-0.126	0.822***	-0.269***	-0.791***	-0.131***
	(0.105)	(0.254)	(0.095)	(0.214)	(0.033)
$A_{Mexico,i}$	0.255***	0.390***	0.086	0.491***	-0.008
	(0.086)	(0.144)	(0.058)	(0.134)	(0.019)
$A_{USA,i}$	-2.105***	-7.935***	0.973	2.786**	0.979***
	(0.748)	(1.710)	(0.601)	(1.327)	(0.225)
$B_{Argentina,i}$	1.013***	-0.424***	0.086***	0.301***	0.060***
	(0.030)	(0.082)	(0.028)	(0.070)	(0.011)
$B_{Brazil,i}$	-0.041*	1.316***	-0.086***	-0.258***	-0.049***
	0.023	(0.071)	(0.021)	(0.059)	(0.009)
$B_{Chile,i}$	-0.264*	2.075***	0.467***	-1.435***	-0.287***
	(0.148)	(0.308)	(0.114)	0.227)	(0.032)
$B_{Mexico,i}$	0.151	-1.319***	0.229***	1.602***	0.158
	(0.093)	(0.126)	(0.063)	(0.121)	(0.012)
$B_{USA,i}$	-2.658	19.149***	-4.168***	-11.807***	-1.539***
	(0.126)	(1.813)	(0.818)	(1.807)	(0.118)
AIC	-11.747	BIC			-10.582
Panel C - Robust tests for model standardized residuals					
	Argentina	*Brazil*	*Chile*	*Mexico*	*US*
Mean	-0.081	-0.059	-0.095	-0.095	-0.083
Standard deviation	0.998	1.024	0.994	0.972	0.974
Skewness	-0.242	-0.600	-0.596	-0.725	-0.586
Kurtosis	1.838	1.873	1.751	0.612	0.396
JB	38.101^{+++}	61.453^{+++}	47.277^{+++}	26.109^{+++}	16.115^{+++}
Q(12)	7.070	7.071	8.425	19.538^{+}	14.362
ARCH(12)	21.590^{++}	12.006	14.429	6.919	5.816

Notes: Bollerslev and Wooldridge (1992)'s robust standard errors are given in parentheses. JB is the Jarque-Bera test for normality. Q(12) is the Ljung-Box test for autocorrelation of order 12. ARCH is the Engle (1982) test for conditional heteroscedasticity. ***, ** and * indicate significance of coefficients at the 1%, 5%, and 10% respectively. $^{+++}$, $^{++}$ and $^{+}$ indicate rejection of the null hypotheses of no autocorrelation, normality, and homoscedasticity at the 1%, 5%, and 10% levels of significance respectively for statistical tests.

Table 3. Estimation results of the DCC-MGARCH model

Panel A – parameter estimates of the mean equations					
	Argentina	*Brazil*	*Chile*	*Mexico*	*US*
δ_0	0.0077	0.010	0.009**	0.013	0.006***
	(0.007)	(0.011)	(0.004)	(0.013)	(0.002)
δ_1 (1st lag of local market returns)	-0.028	-0.047	0.127**	-0.007	-0.019
	(0.058)	(0.105)	(0.066)	(0.058)	(0.058)
δ_2 (current lag of the US market returns)	0.559**	0.224	0.110	0.440***	---
	(0.246)	(0.397)	(0.136)	(0.147)	
δ_3 (1st lag of the US market returns)	0.244	0.187	0.062	0.142	-0.019
	(0.177)	(0.223)	(0.091)	(0.128)	(0.058)
Panel B - parameter estimates of the variance processes					
	Argentina	Brazil	Chile	Mexico	US
ϖ_0	0.001	0.026**	0.006***	0.001	0.000
	(0.001)	(0.013)	(0.001)	(0.001)	(0.000)
ϖ_1	0.134*	0.121	0.059	0.121***	0.174***
	(0.042)	(0.113)	(0.044)	(0.048)	(0.031)
ϖ_2	0.853*	0.189	0.470*	0.875***	0.826***
	(0.053)	(0.327)	(0.278)	(0.055)	(0.031)
Variance persistence $[(\varpi_1 + \varpi_2)]$	0.987	0.310	0.529	0.996	1.000
α	0.065***				
	(0.023)				
β	0.394***				
	(0.159)				
AIC	-11.981	BIC			-10.800
Panel C - Robust tests for model standardized residuals					
	Argentina	Brazil	Chile	Mexico	US
Mean	-0.017	-0.019	-0.021	-0.036	-0.020
Std-Dev.	1.018	0.996	0.981	0.991	0.954
Skewness	0.228	-1.917	-0.626	-1.105	-0.656
Kurtosis	2.053	12.424	2.554	4.349	1.047
JB	47.004+++	1796.291+++	86.019+++	252.924+++	29.991+++
Q(12)	4.107	16.059	7.224	19.164+	13.152
ARCH(12)	11.288	16.084	13.433	3.071	3.277

Notes: Bollerslev and Wooldridge (1992)'s robust standard errors are given in parentheses. ϖ_0, ϖ_1 and ϖ_2 refer to the parameters of a GARCH(1,1) process. JB is the Jarque-Bera test for normality. Q(12) is the Ljung-Box test for autocorrelation of order 12. ARCH is the Engle (1982) test for conditional heteroscedasticity. ***, ** and * indicate significance of coefficients at the 1%, 5%, and 10% respectively. +++, ++ and + indicate rejection of the null hypotheses of no autocorrelation, normality, and homoscedasticity at the 1%, 5%, and 10% levels of significance respectively for statistical tests.

The coefficients relating the return series to the one-lag local (Panel A) of Tables 2-3 are insignificant, except for Chile where current returns are predictable from their AR(1) values if one considers the DCC-GARCH results. Lagged US market returns are also insignificant except for Argentina based of the BEKK-GARCH model findings. The effects of the US current stock returns on the dynamics of emerging stock returns are significant only in the cases of Argentina and Mexico based on the DCC-GARCH model and Brazil and Mexico based of the BEKK-GARCH model. One can explain this finding by a high degree of stock-market integration, particularly between Mexico and the US. This result is consistent with that of Johnson and Soenen (2003) who use Geweke measures of feedback and find about 91% of contemporaneous association between the United States and Mexico. In their study, the same-day responses of Argentinean stock markets to the US ones are also significant. Our result confirms, to the fullest extent, the evidence of increased integration between Latin American emerging markets and the US markets, as documented by Choudry (1997) and Aggarwal and Kyaw (2005) on the basis of unit root and cointegration tests.

Next, consider the ARCH and GARCH coefficients reported in Panels B in Tables 2-3, they are significant at the conventional levels in most cases. This is consistent with the time-varying volatility and justifies our choice of a GARCH-type model. More specifically, The ARCH coefficients are relatively small in size, which indicates that conditional volatility does not change very rapidly. However, the GARCH coefficients are large, indicating gradual fluctuations over time. It is equally important to note that the DCC estimates, $\alpha = 0.065$ and $\beta = 0.394$, are significantly different from zero at the 1% level and satisfy the mean-reverting condition $\alpha + \beta \prec 1$. This typically implies that the conditional volatility of the sample stock markets slows to adjust to their "normal" equilibrium level, which is governed by the state of the economy.

Panels C of Tables 2 and 3 provide some diagnostics of the models residuals in order to assess the appropriateness of the empirical model. The indices of kurtosis in the filtered return series are lower in most cases than what we found for the raw returns (Table 1). Unfortunately, the results of the Jacque-Bera test for normality do not support the proposition that the conditionally normal GARCH process is sufficiently fat-tailed to accommodate the excess kurtosis in the data. We also apply the Ljung-Box test for autocorrelation and the Engle (1982)'s test for ARCH effects to the estimated residuals and find that our specifications is powerful enough to capture the dynamics of the returns and the conditional covariance matrix. These tests further suggest that the DCC-GARCH model outperforms the BEKK-GARCH model as the AIC and SIC criteria are clearly lower for the DCC model than for the BEKK model. In the rest of the article, we continue our analysis based on the DCC estimates.

Figure 2 shows the patterns of dynamic conditional correlations among the markets under consideration together with their 95% confidence levels, as obtained from the DCC-GARCH model. Several interesting observations can be made. First, cross-market dynamic correlations are positive throughout the study period, confirming that the sample stock markets exhibit a certain degree of financial interdependence and significant comovements. They are relatively low and average 0.401 for the whole sample. The average correlation of the Latin American markets and the US market is 0.422, compared to 0.387 for the emerging universe. These findings are in agreement with evidence in the literature that global integration in Latin American stock markets proceeds faster than regional integration (Barari, 2004).

Second, the dynamic linkages between stock markets vary considerably over time and bear witness to some periods of great instability. The highest conditional correlations were observed in November 2008 during the global financial crisis period. In fact, during that month, the cross-market conditional correlations grew to 0.656 on average, while the average correlation of emerging and US markets increased to 0.700. Other important peaks of market comovement were observed during the Mexican crises (1994), during the Asian crisis (1997-1998), and after the terrorist attacks on the US World Trade Center (2001). For US investors, this should mean low diversification gains from adding Latin American emerging market assets during these crisis periods. Note however that for all the abrupt jumps observed, the correlations did not increase sharply at the start of the crisis, which implies that crisis shock transmission among markets is not immediate but occurs with a certain time lag.

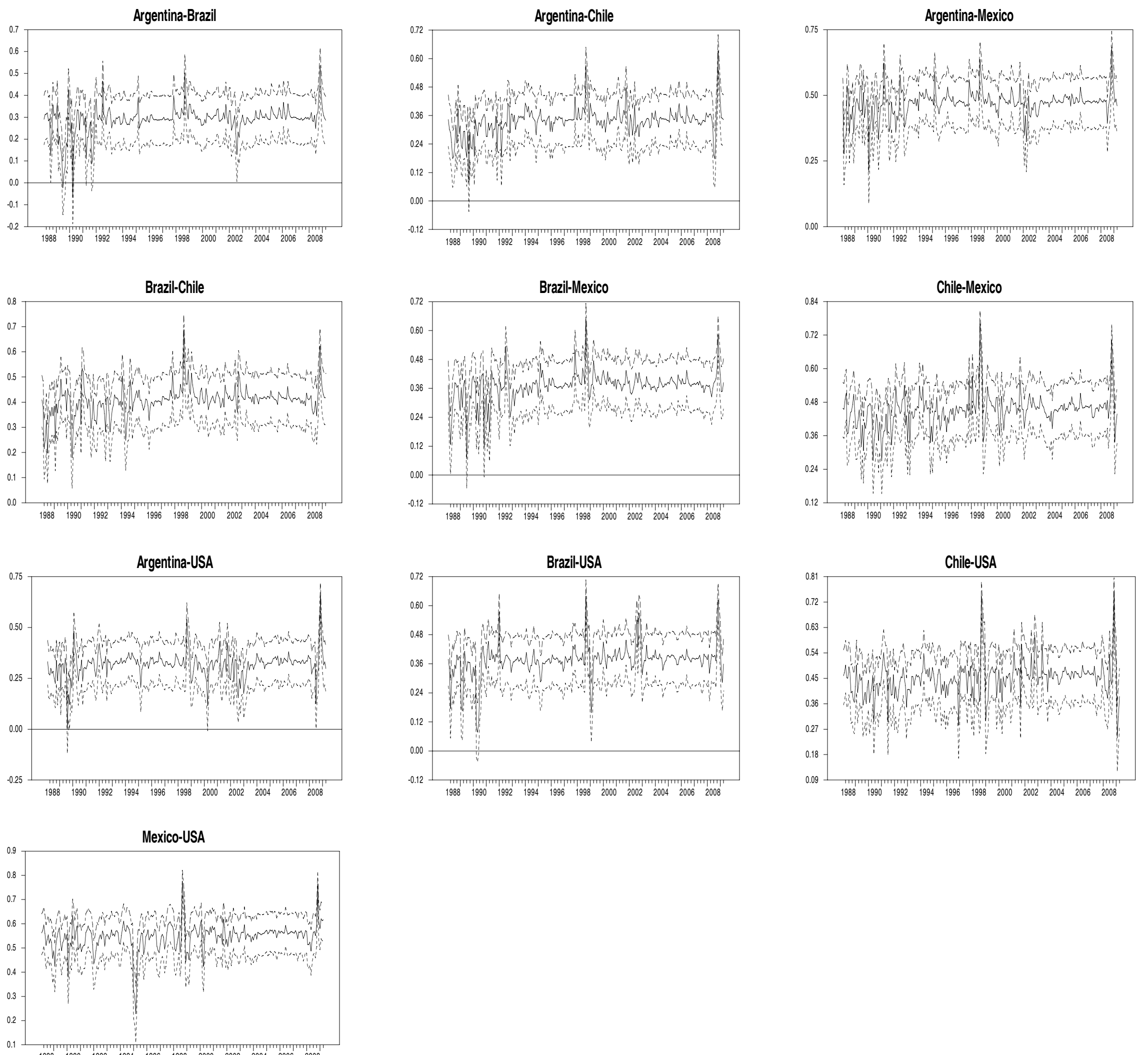

Figure 2. Dynamic conditional correlations between studied markets

Third, contrary to expectation, there was a notable drop in conditional correlations between Mexico and the US in March 1995, just after the start of the debt crisis marked by the peso's 34% fall. This behavior indicates that the contagion effect was not present, and can be explained by the reimposition of controls on foreign ownership and the increase in the capital limit requirements for banks. For example, the Mexican government decided to reduce the maximum amount of equity in a NAFTA affiliate bank that a NAFTA investor was authorized to hold from 99% to only 51%.

Finally, despite the fact that emerging markets have become more open to foreign direct investments and portfolio flows following the market liberalization policies of the 1990s, dynamic correlations in Figure 2 seem to indicate that their financial links with the US did not strengthen significantly.

Summarizing all of the above, the correlations of four emerging markets with the US market vary over time, and reached some peaks, but their levels did not greatly change after crises. These results, in line with the findings of Diamandis (2009), suggest that US investors may still benefit from including assets issued by Latin American stock markets in their portfolios.

3.3 Structural Changes

We now turn to investigate whether any structural change has occurred in conditional correlations between studied Latin American emerging markets and the US market over the estimation period The Bai and Perron (2003)'s testing procedure, described in Section 2, was applied to detect and date the structural breakpoints. The optimal number of breakpoints (*m*) should be the one associated with the minimum BIC. In Table 4 we report the selected optimal breakpoints for each market together with their 95% confidence intervals.

The null hypothesis of stability is rejected for all the markets, since the Bai-Perron test detects at least one breakpoint in the correlations of all four emerging markets with the US. In Argentina, three significant breakpoints are obtained, while in the three remaining countries one breakpoint is detected. This implies a clear change in the nature of the comovement structure, and thus has important implications for market authorities and global investors in managing their coordination policies and portfolios respectively. For instance, an upward trend in inter-market comovement after a structural break would tend to reduce the allocation rate of a US investor's portfolio into Latin American markets.

Another interesting question arising from structural change analysis is whether the break dates estimated from Bai and Perron's procedure coincide with important market events in the various counties under consideration. We first observe that the break dates in the correlations of three emerging markets with the US occurred around the time of the Asian financial crisis of 1997-1998 (Argentina, Chile, and Mexico). Other crisis episodes did not appear to cause structural changes in market comovements.

We then attempt to match the remaining break dates with the liberalization events in emerging markets obtained from Bekaert and Harvey (2000). As market liberalization may imply important changes in a country's economic infrastructure, structural changes in cross-market relationship are likely to occur. Accordingly, we find that the official liberalization date in Brazil (May 1991) falls within the 95% confidence intervals of the correlation break, whereas the 95% confidence intervals of one correlation break in Argentina contain the dates of the first ADR (American Depository Receipt) and country fund introduction (August and October 1991 respectively) as well as the date of a break in US capital flows to Argentina (March 1993).

Table 4. Estimates of structural breakpoints in the conditional correlations with the US markets based on DCC-GARCH estimates

Countries	*Test parameters*			*Optimal breakpoints*			
	Best m breakpoints	*RSS*	*BIC*	*Optimal number of breakpoints*	*Estimated breakpoint dates*	*95% confidence levels for breakpoint dates*	
						Lower bound	*Upper bound*
Argentina-US	0	0.8961	-706.2539	3	Mar-91	Oct-90	Jun-93
	1	0.8379	-712.2976				
	2	0.8218	-706.1763		Dec-98	Oct-96	Oct-99
	3	0.7677	**-712.4295**				
	4	0.7641	-702.5746		Nov-03	Mar-02	Aug-05
	5	0.7806	-686.0250				
Brazil-US	0	0.9864	-681.7696	1	Mar-91	Oct-90	Mar-93
	1	0.8464	**-709.7081**				
	2	0.8303	-703.5334				
	3	0.8234	-694.5772				
	4	0.8217	-684.0340				
	5	0.8191	-673.7593				
Chile-US	0	0.8565	-717.7826	1	Aug-98	Nov-94	Mar-00
	1	0.7875	**-728.1122**				
	2	0.7759	-720.8143				
	3	0.7708	-711.4178				
	4	0.7695	-700.7624				
	5	0.7700	-689.5067				
Mexico-US	0	0.7236	-760.7628	1	Jun-97	Oct-95	Oct-00
	1	0.6599	**-773.2063**				
	2	0.6482	-766.6577				
	3	0.6434	-757.5006				
	4	0.6388	-748.2408				
	5	0.6371	-737.8267				

Notes: The breakpoint selection procedure in the works of Bai and Perron (2003) is based on the Bayesian Information Criteria (BIC). We arbitrarily set the maximum number of breaks to be 5. If the effective number of breaks is equal to 5, a higher number of breaks will be chosen so that the testing procedure captures all possible breakpoints. A model's optimal number of breakpoints should be the one associated with the minimum BIC. For the countries considered in this present study, none of the volatility series has more than 5 breakpoints.

Overall, major stock market events such as financial crises, official liberalizations, and ADR and country fund introduction have significant impacts on the comovements of Latin American markets. Their correlations with the US generally increased in the year following the lifting of investment barriers.

3.4 Comovement Asymmetries around Financial Crises

Most previous studies on developed and emerging stock markets suggest that the comovement of stock markets is stronger during a crisis period than during normal or tranquil ones. In this article we test this assertion by investigating the differences in the level of conditional correlations for three crisis periods: the Mexican crisis (1994), the Asian crisis (1997), and the subprime crisis (2007). More specifically, we compare the average correlation of each emerging market with the US market 24 months prior to the crises, to those computed 24 months after the crises. The event window is shorter for the global financial crisis of 2007-2008 (22 months before and after the crisis) owing to insufficient data points at the time this research was performed. Our method consists of using a simple two-tailed parametric test, called a T-test to compare the means between two subperiods. This test investigates the null hypothesis of no increase in correlations; the empirical *t*-statistic, used to make test decisions, is given by

$$t^* = \frac{(\bar{x} - m)}{(s/\sqrt{n})}$$

where $\bar{x}$ refers to the average correlation of the crisis period, m is the average of the tranquil period, s refers to the unbiased standard deviation of the crisis period, and n is equal to 24. Assume that the conditional correlation series is normally distributed, then under the null hypothesis of no increase in correlations the t^* follow a Student-*t* distribution with (*n*-1) degrees of freedom.[5]

Tables 5, 6, and 7 report the T-test results for the three crisis episodes we consider. As far as the Mexican crisis is concerned, the post-crisis correlations are lower than the pre-crisis ones. The T-test rejects the null hypothesis of no increase in correlations for three markets: Argentina (at the 10% level), Chile (5%), and Mexico (1%). Given the symmetry of the Student-*t* distribution and the negative values of empirical *t*-statistics, the test results indicate that cross-market correlations did not increase significantly after the Mexican crisis. The change in correlation for Brazil is not significant.

In sharp contrast to the previous crisis, the 24-month average comovement between Latin American emerging and US markets rose in three countries (Brazil, Chile, and Mexico) following the Asian financial crisis of 1997-1998, but according to the T-test results this positive increase is only significant for Mexico (Table 6).

Turning to the global financial crisis of 2007-2008, which is often compared to the Great Depression in 1929 for its harmful impacts on world economy, no significant change in inter-market comovements is observed, as the null hypothesis of the T-test cannot be rejected. This finding is particularly interesting because the US mortgage crisis has spread to almost all areas of the globe, including the financial markets in Latin America, and many economists pleaded in favor of contagion effects.

In sum, our findings do not support the proposition according to which Latin American stock markets tend to comove much more with the US stock markets during times of crisis than during normal times. In other words, US investors would still benefit from investing in these markets, provided that they are aware of significant peaks of comovement in times of crisis and possible changes in the nature of the cross-market comovement structure. A reassessment of stock market comovements is thus necessary before implementing any investment strategy in Latin America, and in particular in a follow-up of major stock market events.

5 Using a standard *Z*-test after standardizing the correlation coefficients of the two subperiods according to the Fisher transformation formula, the results remain intact.

Table 5. Test of changes in dynamic conditional correlations around the 1994 Mexican crisis

Pre-crisis period: December, 1992 to November 1994	*ARG-US*	*BRA-US*	*CHI-US*	*MEX-US*
Mean	0.336	0.367	0.448	0.559
Std. Dev.	0.020	0.022	0.037	0.024
Jarque-Bera	0.043	0.424	2.306	0.109
Probability	0.979	0.809	0.316	0.947
Post-crisis period: December, 1994 to November, 1996	*ARG-US*	*BRA-US*	*CHI-US*	*MEX-US*
Mean	0.325	0.365	0.435	0.496
Std. Dev.	0.032	0.026	0.028	0.094
Jarque-Bera	61.297	35.247	0.192	13.604
Probability	0.000	0.000	0.908	0.001
T-test for the null hypothesis of mean equality				
Changes in means	-0.011	-0.002	-0.014	-0.063
t-statistics	-1.751	-0.455	-2.424	-3.275
p-value	0.093	0.654	0.024	0.003

Notes: *t*-statistics and *p*-values refer respectively to the empirical statistics and the associated probability of the two-tailed Student-*t* test for the null hypothesis of no increase in correlations. The T-test was chosen owing to the non-normality of sample data. Jarque-Bera denotes the empirical statistic of the test for normality of the series studied.

Table 6. Test of changes in dynamic conditional correlations around the 1997 Asian crisis

Pre-crisis period: July, 1995 to June, 1997	*ARG-US*	*BRA-US*	*CHI-US*	*MEX-US*
Mean	0.327	0.367	0.440	0.511
Std. Dev.	0.028	0.025	0.041	0.081
Jarque-Bera	114.469	31.329	37.506	46.335
p-value	0.000	0.000	0.000	0.000
Post-crisis period: July, 1997 to June, 1999	*ARG-US*	*BRA-US*	*CHI-US*	*MEX-US*
Mean	0.317	0.386	0.454	0.557
Std. Dev.	0.068	0.073	0.084	0.071
Jarque-Bera	21.015	35.378	20.328	5.753
p-value	0.000	0.000	0.000	0.056
T-Test for the null hypothesis of mean equality				
Changes in means	-0.011	0.019	0.014	0.046
t-statistics	-0.925	1.546	0.969	3.889
p-value	0.362	0.131	0.339	0.000

Notes: see notes to Table 5.

Table 7. Test of changes in dynamic conditional correlations around the 2007-2008 global financial crisis

Pre-crisis period: September, 2005 to June, 2007	*ARG-US*	*BRA-US*	*CHI-US*	*MEX-US*
Mean	0.334	0.382	0.468	0.564
Std. Dev.	0.015	0.013	0.011	0.011
Jarque-Bera	11.668	5.043	3.198	5.251
p-value	0.003	0.080	0.202	0.072
Post-crisis period: July, 2007 to April, 2009	*ARG-US*	*BRA-US*	*CHI-US*	*MEX-US*
Mean	0.341	0.396	0.456	0.572
Std. Dev.	0.096	0.073	0.100	0.056
Jarque-Bera	23.005	15.587	8.586	32.163
p-value	0.000	0.000	0.014	0.000
T-Test for the null hypothesis of mean equality				
Changes in means	0.006	0.013	-0.012	0.008
t-statistics	0.308	0.873	-0.579	0.650
p-value	0.761	0.393	0.569	0.523

Notes: see notes to Table 5.

4. Conclusion

This article examines the comovements between four major Latin American emerging stock markets (Argentina, Brazil, Chile, and Mexico) and the US stock market based on two competing multivariate GARCH models (DCC and BEKK specifications) over the period from February 1988 to April 2009. Moreover, we apply the Bai and Perron (2003)'s structural change test on the correlations obtained from the selected model to investigate time-variation in comovements between the stock markets under consideration. Our method thus enables us to study not only the time-varying trend in market comovements (or more broadly the regional and global integration of Latin American emerging markets), but also the changing nature of these comovements.

Several interesting findings emerge from our empirical investigation. First, the DCC-GARCH model gives better results than the BEKK model. Second, the obtained time-varying correlations show significant market linkages between Latin American and US stock markets. However, these correlations remain below 0.50 almost all the time, which suggests significant diversification benefits from investing in Latin American stock markets. In particular, the US markets allow us to explain the contemporaneous dynamics of stock returns in several cases. Second, we document the presence of at least one structural breakpoint in the dynamic conditional correlations of emerging markets and the US market. These breakpoints are generally found to coincide with some major market events such as a financial crisis and stock market reforms. Third, our results are not consistent with the view that contagion effects exist during times of crisis, based on sample market data. Correlations increased significantly only in the aftermath of the Asian crisis in the case of Mexico and the US.

References

Aggarwal, R., Kyaw, N.A., (2005), "Equity market integration in the NAFTA region: Evidence from unit root and cointegration tests", *International Review of Financial Analysis*, 14, 393-406.

Bae, K., Karolyi, G.A., Stulz, R.M., (2003), "A new approach to measuring financial contagion", *Review of Financial Studies*, 16, 717-763.

Bai, J., Perron, P., (2003), "Computation and analysis of multiple structural change models. Journal of Applied Econometrics", 18, 1-22.

Barari, M., (2004), "Equity market integration in Latin America: A time-varying integration score analysis", *International Review of Financial Analysis*, 13, 649-668.

Bekaert, G., Harvey, C.R., (1995), "Time-varying world market integration", *Journal of Finance*, 50, 403-444.

Bekaert, G., Harvey, C.R., (1997), "Emerging equity market volatility", *Journal of Financial Economics*, 43, 29-78.

Bekaert, G., Harvey, C.R., (2000), "Foreign speculators and emerging equity markets", *Journal of Finance*, 55, 565-613.

Bollerslev, T., (1986), "Generalized autoregressive conditional heteroscedasticity", *Journal of Econometrics*, 31, 307-327.

Bollerslev, T., Wooldridge, J.M., (1992), "Quasi maximum likelihood estimation and inference in dynamic models with time-varying covariances", *Econometric Review*, 11, 143-172.

Bollerslev, T., (1990), "Modelling the coherence in short-run nominal exchange rate: A multivariate generalized ARCH approach", *Review of Economics and Statistics*, 72, 498-505.

Carrieri, F., Errunza V., Hogan, K., (2007), "Characterizing world market integration through time", *Journal of Financial and Quantitative Analysis*, 42, 511-540.

Chan-Lau, J.A., Mathieson, D.J., Yao, J.Y., (2004), "Extreme contagion in equity markets", IMF Staff Papers 51, 386-408.

Chen, G-M., Firth, M., Rui, O.M., (2002), "Stock market linkages: Evidence from Latin America", *Journal of Banking and Finance*, 26, 1113-1141.

Chiang, T.C., Jeon, B.N., Li, H., (2007), "Dynamic correlation analysis of financial contagion: Evidence from Asian markets", *Journal of International Money and Finance*, 26, 1206-1228.

Choudry, T., (1997), "Stochastic trends in stock prices: Evidence from Latin American markets", *Journal of Macroeconomics*, 19, 285-304.

Christofi, A., Pericli, A., (1999), "Correlation in price changes and volatility of major Latin American stock markets", *Journal of Multinational Financial Management*, 9, 79-93.

De Melo Mendes, B.V., (2005), "Asymmetric extreme interdependence in emerging equity markets", *Applied Stochastic Models in Business and Industry*, 21, 483-498.

Diamandis, P.F., (2009), "International stock market linkages: Evidence from Latin America", *Global Finance Journal*, 20, 13-30.

Engle, R.F., Granger, C.W.J., (1987), "Co-integration and error correction: representation, estimation and testing", *Econometrica*, 55, 251-276.

Engle, R.F., (1982), "Autoregressive conditional heteroscedasticity with estimates of the variance of UK inflation", *Econometrica*, 50, 987-1008.

Engle, R.F., (2002), "Dynamic conditional correlation: a new simple class of multivariate GARCH models", *Journal of Business and Economic Statistics*, 20, 339-350.

Engle, R.F., Kroner, K.F., (1995), "Multivariate simultaneous generalized ARCH", Working Paper, University of California, San Diego.

Errunza, V., (1977), "Gains from portfolio diversification into less developed countries' securities". *Journal of International Business Studies*, 52, 83-99.

Forbes, K., Rigobon, R., (2002), "No contagion, only interdependence: measuring stock market comovements", *Journal of Finance*, 57, 2223-2261.

Fujii, E., (2005), "Intra and inter-regional causal linkages of emerging stock markets: Evidence from Asia and Latin America in and out of crises", *International Financial Markets, Institutions and Money*, 15, 315-342.

Geweke, J., (1982), "Measurement of linear dependence and feedback between multiple time series", *Journal of the American Statistical Association*, 77, 304-313.

Gilmore, C.G., Lucey, B.M., McManus, G.M., (2008), "The dynamics of central European equity market comovements", *Quarterly Review of Economics and Finance*, 48, 605-622.

Granger, C.J., (1969), "Investigating causal relationships by econometrics models and cross spectral methods", *Econometrica*, 37, 425-435.

Hamao, Y., Masulis, R.W., Ng, V., (1990), "Correlations in price changes and volatility across international markets", *Review of Financial Studies*, 3, 281-307.

Hsin, C-W., (2004), "A multilateral approach to examining the comovements among major world equity markets", *International Review of Financial Analysis*, 13, 433-462.

Johnson, R., Soenen, L., (2003), "Economic integration and stock market comovement in the Americas", *Journal of Multinational Financial Management*, 13, 85-100.

Karolyi, G.A., (1995), "A multivariate GARCH model of international transmissions of stock returns and volatility: The case of the United States and Canada", *Journal of Business and Economic Statistics*, 13, 11-25.

Kasa, K., (1992), "Common stochastic trends in international stock markets", *Journal of Monetary Economics*, 29, 95-124.

Kearney, C., Poti, V., (2006), "Correlation dynamics in European equity markets", *Research in International Business and Finance*, 20, 305-321.

Kim, E.H., Singal, V., (2000), "Stock market openings: Experience of emerging economies", *Journal of Business*, 73, 25-66.

Lahrech, A., Sylwester, K., (2011), "U.S. and Latin American stock market linkages", *Journal of International Money and Finance*, 30, 1341-1357.

Li, H., (2007), "International linkages of the Chinese stock exchanges: A multivariate GARCH analysis", *Applied Financial Economics*, 17, 285-295.

Li, H., Majerowaska, E., (2007), "Testing stock market linkages for Poland and Hungary: A Multivariate GARCH approach", *Research in International Business and Finance*, 22, 1-20.

Longin, F., Solnik, B., (2001), "Extreme correlation of international equity markets", *Journal of Finance*, 56, 649-676.

Lundblad, C., (2007), "The risk return tradeoff in the long run: 1836-2003", *Journal of Financial Economics*, 85, 123-150.

Morana, C., Beltratti, A., (2008), "Comovements in international stock markets", *Journal of International Financial Markets, Institutions and Money*, 18, 31-45.

Sims, C.A., (1980), "Macroeconomics and reality", *Econometrica*, 48, 1-48.

Syriopoulos, T., (2007), "Dynamic linkages between emerging European and developed stock markets: Has the EMU any impact?", *International Review of Financial Analysis*, 16, 41-60.

Syriopoulos, T., Roumpis, E., (2009), "Dynamic correlations and volatility effects in the Balkan equity markets", *Journal of International Financial Markets, Institutions and Money*, 19, 565-587.

Taylor, M.P., Tonks, I., (1989), "The internationalisation of stock markets and the abolition of U.K. exchange control", *Review of Economics and Statistics*, 71, 332-336.

Worthington, A., Higgs, H., (2004), "Transmission of equity returns and volatility in Asian developed and emerging markets: A multivariate GARCH analysis", *International Journal of Finance and Economics*, 9, 71-80.

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