Financial Contagion in Latin America

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Abstract

This study uses a Dynamic Conditional Correlation multivariate GARCH approach for testing for contagion among Latin American financial markets to shocks originated in the United States and Europe. Using daily data on stock market returns for the period comprised between July 4th, 2001 and December 30th, 2013, we find some evidence suggesting two episodes of contagion. The first corresponds to the time of the mortgage subprime crisis in the US, while the second corresponds to the period of sovereign bonds' turbulence in Europe.

JEL Classification: *G01; G15; C32.*

Keywords: *Financial contagion; Financial crises; Multivariate GARCH models.*

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1. Introduction

One of the most feared side-effects of financial globalization is financial contagion. Several studies have documented the negative effects of the propagation of shocks originating in an economy to other countries. The history of financial crises and particularly the recent 2007-09 financial turmoil clearly illustrate the drawbacks of financial market integration. However, although the term is commonly associated with panic and financial disruption, there is widespread disagreement about what financial contagion entails.

In this study we follow Forbes and Rigobon (2002), who define contagion in terms of significant increases in international cross-market linkages following the occurrence of a shock to one country. In this sense, contagion relates to the behavior of market interdependence after the happening of a shock. Defining contagion this way has two advantages. First, testing for contagion among financial markets is straightforward. It suffices to compare linkages between pairs of markets during periods of stability with their linkages during episodes of financial turbulence (see, for instance, Loaiza-Maya et al., 2015a). Second, it allows distinguishing between permanent and temporal mechanisms of crises transmission. Identifying if the propagation of a crisis is due to permanent or temporal mechanisms has important implications for designing public policy responses.

Our focus is on studying the propagation of shocks originated in developed economies' stock markets to the stock markets of the six major Latin American countries. Particularly, we seek to identify episodes of contagion in Latin American stock markets after the occurrence of shocks to those markets of the United States and Europe. We use daily stock market data for the period comprised between July 4th , 2001 and December 30th , 2014, and apply the Dynamic Conditional Correlation (DCC) multivariate GARCH model of Engle (2002) for identifying periods of contagion between pairs of markets. This model, which parameterizes the conditional correlations directly, has the advantage of providing the flexibility of univariate GARCH without the complexity of conventional multivariate GARCH models. Additionally, these models offer an important advantage over multivariate GARCH models, because the number of parameters to be estimated in the correlation process is independent of the number of series to be correlated.

Our results show that, in most cases, there are statistically significant increases in conditional correlations between the stock markets of the Latin American countries considered in this study during two periods. The first, comprised between 2007 and 2009, corresponding to the subprime international financial crisis. The second, between 2011 and 2012, corresponds to the recent European sovereign bond crisis. These findings go in line with those obtained by Syllignakis and Kouretas (2011), who identify an episode of contagion in Central and Eastern European markets originated in the United States subprime crisis of 2007-09.

Our contributions to the literature are two-folded. First, this study is, up to our knowledge, the first in focusing in Latin American economies in testing for contagion after the occurrence of an external negative shock, using a sample period which covers three major external financial crises. Second, it is also the first to study the effects of both the subprime mortgage crisis in the United States and the more recent sovereign European bond crisis in a set of emerging economies.

Studying interdependence in Latin American financial markets is important for at least two main reasons. On the one hand, financial contagion has not been sufficiently explored in these markets. The only previous study focusing on stock markets of this region is Chen et al. (2002), but the approach is substantially different from the one followed in this study.

On the other hand, and more importantly, after the recent global financial crisis emerging markets (and particularly Latin American countries) became an important destiny of investment. In this context of large capital inflows, it is of major importance to better understand interdependencies among Latin American markets in order to make reliable and profitable portfolio decisions.

The rest of the paper is organized as follows. Section 2 presents a brief literature review. Section 3 presents the data and shows our main results. Finally, the last section concludes.

2. Literature review

Studying correlations among assets and across markets is the starting point for building a global portfolio diversification strategy. Almost seventy years ago Markovitz (1952) derived an optimal rule for allocating wealth among risky assets in a static context with investors caring only about the mean and variance of the portfolio's return. However, as it has widely been shown in the literature, asset return correlations vary over time. Generally speaking, they tend to rise in bear markets and decline in bull markets (e.g. Ang and Bekaert, 1999). Hence, notable effort has been devoted to extend Markovitz setting to a dynamic context which considers these stylized facts. For a general survey of the literature on portfolio selection, see Brandt (2007).

Major financial crises, like the Mexican tequila crisis of 1994, the Asian financial crisis of 1997, the Russian default of 1998 and the international financial crisis of 2007-09 have clearly illustrated the fact that correlations among international financial markets increase during times of financial turbulence and high market volatility. Thus, benefits of portfolio diversification strategies are easier to achieve during times of financial tranquility.

Although there is not a unified definition of financial contagion, several authors have proposed defining it in terms of signifficant differences in market correlations during normal times and during times of elevated financial turbulence. Particularly, Forbes and Rigobon (2002) define contagion in terms of significant increases in international cross-market linkages following the occurrence of a shock to one country (or a set of countries). In this sense, contagion relates to the behavior of market interdependence after the happening of a shock. Taking this definition as the starting point has several advantages in performing tests of contagion, as shown by Ang and Chen (2002), Bae et al. (2003), Bekaert and Harvey (2003), Prasad et al. (2003), Loaiza-Maya et al. (2015a, 2015b), among many others. The main two advantages are testing simplicity and the possibility of distinguishing between permanent and temporal mechanisms of crises transmission.

Several aspects must be considered when using correlations in testing for contagion. For instance, the test should be designed in such a way that it properly accounts for the presence of heteroskedasticity in the assets' returns. Login and Solnik (2001) show that changes in correlations are due both to changes in volatility and to the trend followed by the market at each point in time. Particularly, increases in correlations are more frequent during times of high volatility and/or bear markets.

Additionally, an adequate testing strategy must account for the well-established fact that correlations change over time (e.g., Login and Solnik, 1995). Hence, a dynamic correlations set-up is required. Correlations tend to be higher during periods of high volatility (see, for instance, Yang, 2005). Chen et al. (2002), studying long-run relations among the stock markets of Argentina, Brazil, Chile, Colombia, Mexico and Venezuela, find that there exists a cointegrating vector explaining price dependencies among these markets. Their results suggest that there is limited potential for diversifying risk by investing in different Latin American markets, as international shocks that affect a particular Latin American stock market propagate to all the other countries' markets due to high interdependence.

The DCC multivariate GARCH model proposed by Engle (2002) has been used in some recent empirical studies on financial contagion. Chiang et al. (2007) use this methodology and show evidence of contagion in nine economies after the Asian financial crisis. As shown by this study, an important advantage of implementing this methodology is the possibility of accounting for heteroskedasticity in stock market returns without having to arbitrarily split the sample as in Forbes and Rigobon (2002). In a related paper, Syllignakis and Kouretas (2011) study contagion in a group of Central and Eastern European countries following the recent international financial crisis. They find evidence of contagion through increases in European stock market linkages. between 2007 and 2009. Horvath and Poldauf (2012) and Kotkatvuori-Ornberg et al. (2013) conduct studies of contagion in different countries after the subprime crisis of 2007-09 in the United States. Both report results that suggest market contagion, especially after the Lehman Brothers failure in September 2008.

Our study is, up to our knowledge, the first in implementing a DCC multivariate GARCH model for testing for contagion in Latin American economies after the occurrence of an external negative shock. It is also the first to study the effects of both the subprime mortgage crisis in the United States and the more recent sovereign European bond crisis in a set of emerging economies.

3. Data and empirical results

The recent empirical literature on contagion has mainly used GARCH models under different representations. The most frequently used representations are the BEKK (Baba et al., 1991 and Engle and Kroner, 1995), the Diagonal VECH and Diagonal BEKK (Bollerslev, 1988), the CCC (Constant Conditional Correlation of Bollerslev, 1990) and the DCC (Engle, 2002). The DCC has been the most popular among those in the most recent literature, given several advantages it offers with respect to the competing alternative representations.[3] In this study we follow this multivariate GARCH approach.

We use daily data on stock indexes for the six largest Latin American economies (Argentina - MERVAL, Brazil - VBOVESPA, Chile - IPSA, Colombia - IGBC, Mexico - IPC and Peru - IGBVL) and for the United States (S&P 500).[4] Our sample spans the periods July 4th, 2001 to December 30th, 2013. The inclusion of the S&P 500 pretends both to control for global factors in our empirical analysis and to test for evidence of contagion during the episodes of the subprime financial crisis and the European sovereign bonds crisis. With the purpose of guaranteeing stationarity we computed the returns of the indexes by taking first differences of their natural logarithms.

Table 1 shows descriptive statistics of the series on stock market returns for our sample of countries. Information on sample means, standard deviations, skewness, kurtosis, Jarque-Bera (JB) tests for normality and Ljung-Box (LB) tests are presented. It is important to highlight that all series exhibit a high kurtosis, as usual in this type of data, and serial correlation.

Table 1. Summary Descriptive Statistics on the Daily Series of Stock Market Returns

	Argentina	Brasil	Chile	Colombia	México	Perú	Estados Unidos
Mean	0.00086	0.00042	0.00038	0.00085	0.00060	0.00081	0.00013
Std. Dev.	0.02120	0.01849	0.01075	0.01354	0.01326	0.01542	0.00921
Skewness	-0.13587	-0.06637	0.47828	-0.20887	0.11871	0.47180	0.19757
Kurtosis	5.30736	5.23748	16.15169	12.59286	5.83845	18.23047	11.76057
LB test	0.0815*	1.028*	0.0564*	0.1553*	0.1037*	0.261*	0.9025*
JB test	4095.58*	789.92*	4195.74*	14970.89*	1132.78*	15601.35*	93830.8*

*Indicates results are statistically significant at the 1% level.

[3] See Engle (2002) for a complete list of the advantages of the DCC representation over other alternative representations of multivariate GARCH models.

[4] In preliminary explorations we included also data on bilateral nominal exchange rates and money market interest rates. However, these variables were not statistically significant and therefore we decided to exclude them from our empirical analysis. This results goes in line with those of Chiang et al. (2007) for Asian economies.

Table 2 shows unconditional Pearson's correlation coefficients between pairs of stock market returns. It can be seen that the minimum correlation between the returns of a Latin American stock market and the S&P 500 is 0.33 (Colombia), while the maximum correlation is 0.60 (Mexico, as expected). Although these preliminary results appear to be intuitive and appealing, it is important to remember that unconditional correlations in this context present serious limitations. Firstly, due to the high frequency of the data it is difficult to evaluate the statistical significance of these coefficients. And secondly, it is also impossible to determine whether correlations vary during different sample sub-periods.

Table 2. Correlation Coefficients between Pairs of Daily Series of Stock Market Returns

	Argentina	Brazil	Chile	Colombia	Mexico	Peru	US
Argentina	1	0.501237	0.417145	0.295772	0.456143	0.396778	0.417685
Brazil	0.501237	1	0.546834	0.337486	0.653150	0.456595	0.534971
Chile	0.417145	0.546834	1	0.346190	0.547725	0.451541	0.516408
Colombia	0.295772	0.337486	0.346190	1	0.373080	0.368467	0.335499
Mexico	0.456143	0.653150	0.547725	0.373080	1	0.446592	0.600969
Peru	0.396778	0.456595	0.451541	0.368467	0.446592	1	0.456701
US	0.417685	0.534971	0.516408	0.335499	0.600969	0.456701	1

Using a DCC multivate GARCH model we are able to overcome these two main drawbacks of simple correlation coefficients. The specification of our model for each country's stock market returns $(r_{i,t})$ is the following:

Mean equation

$$r_{i,t} = \mu_i + \sum_{j=1}^{p_j} \gamma_{i,j} r_{i,t-j} + \phi_i r_t^{US} + \varepsilon_{i,t},$$

For $i = 1, \dots, k$

$$r_t^{US} = \mu_{US} + \sum_{j=1}^{p_{US}} \gamma_j^{US} r_{t-j}^{US} + \varepsilon_{US,t}$$

where $\varepsilon_t = \left(\varepsilon_{1,t}, \dots, \varepsilon_{k,t}, \varepsilon_{US,t}\right)' \backsim (0, H_t)$

DCC equation $H_t = D_t R_t D_t$

where D_t is a diagonal matrix with $[D_t]_{ii} = \sqrt{h_{i,t}}$

$$h_{i,t} = \omega_i + \alpha_i \varepsilon_{i,t-1}^2 + \beta_i h_{i,t-1}$$

with $\omega_i > 0, \quad (\alpha_i, \beta_i) \geq 0, \quad \alpha_i + \beta_i < 1$

$$R_t = Q_t^{*\,-1} Q_t Q_t^{*\,-1}$$

where $Q_t = (1 - a - b)\bar{Q} + a\eta_{t-1}\eta_{t-1}' + bQ_{t-1}$

with $(a, b) \geq 0, \quad a + b < 1$

In this case, $\bar{Q}$ is the unconditional covariance matrix of standardized residuals η_t, $\eta_t = D_t^{-1}\varepsilon_t$, $[Q_t]_{ij} = q_{ij,t}$, and Q_t^* is a diagonal matrix with $[Q_t^*]_{ii} = \sqrt{q_{ii,t}}$, $i = \{Argentina, Brazil, Chile, Colombia, Mexico, Peru\}$, and $k = 6$.

Dynamic correlations, $\rho_{ij,t}$ can be computed between the stock market returns of any pair of countries i and j, using the following equality:

$$\rho_{ij,t} = \frac{q_{ij,t}}{\sqrt{q_{ii,t}}\sqrt{q_{jj,t}}} \qquad (1)$$

Table 3 presents estimation results.[5] Note that all coefficients ϕ_i are positive and statistically significant in each Latin American country's mean equation. This fact reflects the influence of the United States stock markets in the behavior of stock markets in Latin

[5] We specified a different order for each country's mean equation according to indications obtained from information criteria. Financial variables frequently have distributions with larger probabilities in the tails than those used for other economic variables. This is called heavy tails distributions in the literature. According to Ruppert (2004), results in financial analysis may be biased whenever these distributions are not used, as the probability of occurrence of an abnormal event may be underestimated. For this reason, we used a multivariate t-distribution in our specification.

America.[6] Results for the variance equation show that most of the included coefficients are statistically significant at conventional levels. This fact supports the adequacy of our empirical specification.[7] As usual, the sum of coefficients α and β is close to 1, indicating that volatilities are highly persistent.

Table 3. Estimation Results. DCC Multivariate GARC Model (t-statistics in parenthesis)

	Argentina	Brazil	Chile	Colombia	Mexico	Peru	US
Mean equation							
μ_i	0.000555 (0.1942)	0.000120 (0.4797)	0.000548* (3.1280)	0.001040* (4.1668)	0.000488* (3.2184)	0.000931* (3.5198)	0.000678* (3.3407)
ϕ_i	1.015395* (2.2115)	1.048302* (27.2019)	0.495449* (20.2057)	0.351402* (11.0899)	0.796792* (28.7178)	0.468749* (14.5412)	-
Variance equation							
ω_i	0.000007 (0.0445)	0.000004 (0.7943)	0.000003 (1.3172)	0.000017 (3.2543)	0.000002 (0.8624)	0.000007* (1.9328)	0.000001 (0.2076)
α_i	0.093060 (0.2998)	0.065772* (5.7772)	0.148125* (7.6310)	0.215680* (7.2378)	0.075368* (2.5484)	0.214483* (8.5029)	0.108401 (1.2707)
β_i	0.888440* (2.9123)	0.914761* (41.1731)	0.822406* (30.9599)	0.669874* (12.1789)	0.907114* (26.9434)	0.757109* (17.5975)	0.882770* (11.2304)
Multivariate DCC equation							
a	0.006921* (8.2020)						
b	0.989759* (621.4075)						

*Indicates results are statistically significant at the 1% level. Note that the autoregressive coefficients γ_j were estimated for each country but are not reported here.

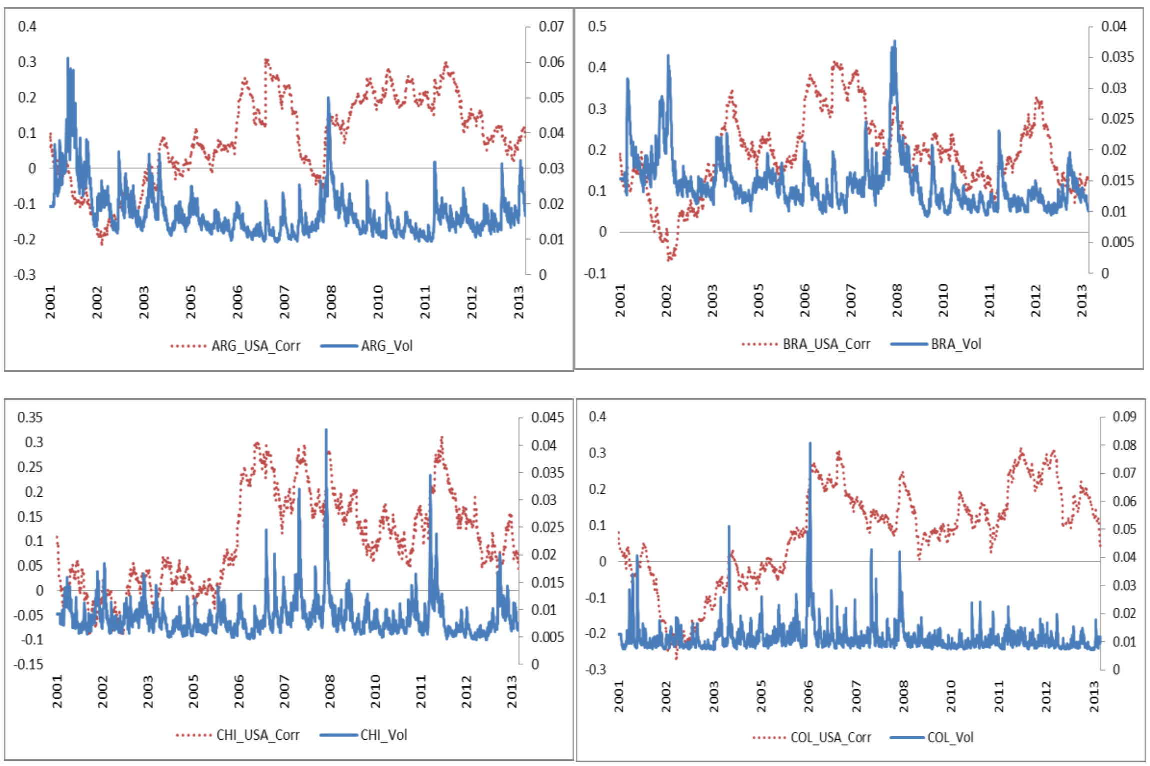
Results obtained from the DCC equation show that the coefficients are statistically significant, suggesting that the returns' co-movements vary over time. The value of these

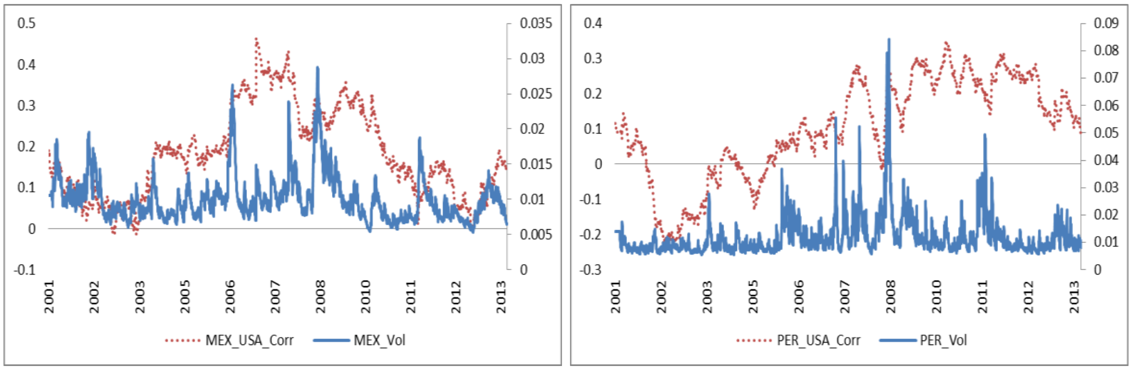
[6] We performed additional exercises in which German and Brazilian stock returns were included as regressors. However, the corresponding coefficients were in most cases not statistically significant at conventional levels. Therefore, we did not include these variables in our main econometrical specifications.
[7] Diagnosis tests (see Appendixes B and C) over the standardized residuals do not show evidence of misspecification. Following Lütkepohl (2005), we used the LM test proposed by Edgerton & Shukur (1999).

coefficients indicates high persistence in correlations (the sum of a and b is close to 0.997).

Figure 1 consists of six panels, each of them containing two graphs. One graph corresponds to the estimated dynamic correlation ($\hat{\rho}_{ij,t}$) between the stock markets' returns of each Latin American country and the United States during the period spanned between July 4th, 2001 and December 30th, 2013. The other graph in each panel depicts the volatility of the corresponding Latin American country's stock market.

Figure 1. Estimated Conditional Correlations and Volatilities, 2001-2013.





As seen from Figure 1, volatilities and correlations vary importantly over time. At the beginning of the sample period some volatility peaks can be observed (common in all six panels). These correspond to the effect of lags of several financial crises experienced by Latin American countries during the late 1990s[8] and the United States Dot-Com bubbles of 2000-2002. During this period correlations of returns between each Latin American stock market and the United States stock market are mainly negative.

Around the international financial crisis of 2007-09 peaks in volatility are also observed, as expected. Indeed these peaks are higher than those observed at the beginning of the sample period for all six countries. However, during this period correlations of stock market returns between Latin American countries and the United States are all positive. The main difference in this period is that the crisis originated in the United States and widespread to most developed and emerging market economies. In fact, volatility is the United States stock market was also very high during this episode (see Figure 2). Correlations were all near to 30% on average during this period of worldwide financial turbulence. By mid-2009 considerable reductions were observed in the value of correlations and volatilities.

During the final part of the sample period another increase in markets' correlations is observed. However, contrasting with earlier periods of high correlations, during this time stock market volatilities remained low in Latin America. This fact might indicate a higher degree of interdependence during this final part of the sample. There is, however, a short

[8] Brazil (1998), Colombia (1998-2000), Argentina (2001).

sub-period during which volatilities in Latin American stock markets were high. This sub-period corresponds to the second semester of 2011. During this sub-period volatility in the United States remained low, though. In an empirical exercise below we show that this market behavior is associated with the effect of the sovereign debt crisis in Europe.

Correlation coefficients during the international financial crisis of 2007-09

The main purpose of this paper consists in testing whether there is evidence of financial contagion in stock markets during episodes of serious financial disruption. For doing so, we follow the methodological proposal of Chiang et al. (2007) and Syllignakis and Kouretas (2011) and perform an empirical exercise to determine whether there is a significant increase in correlations during three different periods of crisis. We use the following regression equation:

$$\rho_{ij,t} = \omega_{ij} + \sum_{k=1}^{3} \alpha_{ij,k} DM_{k,t} + \varepsilon_{ij,t} \qquad (2)$$

where $i = \{Argentina, Brazil, Chile, Colombia, Mexico, Peru\}$ and $j = \{United\ States\}$. We regress correlations $(\rho_{ij,t})$ on a constant term (ω_{ij}) and three dummy variables $(DM_1, DM_{2,} DM_3)$. Each dummy variable takes on the value of one during a different period of financial crisis. The first one (DM_1) corresponds to the Dot-Com bubble (July 4th, 2001 – 27th September, 2002), the second one (DM_2) to the international financial crisis (September 26th, 2008 – September 29th, 2009) and the third one (DM_3) to the European sovereign bond crisis (July 13th, 2011 – January 16th, 2012).[9]

[9] The results obtained in this study are robust to alternative definitions of the periods of crisis.

A period of contagion is cataloged as one in which the corresponding dummy variable is statistically different from zero at conventional significance levels. Table 4 shows regression results.

Table 4. Estimation Results. Dynamic Correlation between the US and Six Latin American Countries (t-statistics in parenthesis)

		Dot-Com Crisis	International Financial Crisis	European Sovereign Bond Crisis
	ω_{ij}	$\alpha_{ij,1}$	$\alpha_{ij,2}$	$\alpha_{ij,3}$
Argentina	0.088974* (5.69)	-0.139469* (-5.80)	0.052267* (2.61)	0.154488* (6.75)
Brazil	0.200115* (15.08)	-0.10586* (-4.17)	0.017799 (0.87)	-0.046792* (-3.08)
Chile	0.100796* (8.59)	-0.102553* (-6.19)	0.083452* (4.68)	0.131175* (5.23)
Colombia	0.075450* (4.15)	-0.107631* (-3.91)	0.046031 (1.49)	0.175404* (6.5338)
Mexico	0.18679* (12.70)	-0.086000* (-4.33)	0.105531* (5.88)	-0.085794* (-4.35)
Peru	0.093948* (4.90)	-0.077484 (-2.14)	0.114237* (4.07)	0.163341* (5.92)

*Indicates results are statistically significant at the 1% level. Standardized errors follow the methodology of Newey and West (1987) for calculating a covariance matrix corrected by heteroskedasticity and autocorrelation. And $j = United\ States$.

Note that the dummies corresponding to the three crises are all statistically significant at the 1% level for all dynamic correlations. However, while during the Dot-Com crisis dynamic correlations between Latin American countries and the United States were all significantly reduced (in fact, most of them became negative), during the other two episodes of crisis most of these coefficients increased significantly (exceptions are Brazil and Colombia, for which no change was registered). This very interesting result indicates that while during the Dot-Com crisis there is no evidence of contagion in the six major Latin American stock markets, during the international financial crisis and the European sovereign bond crisis there is indeed evidence of financial contagion.

The significant reduction of correlations encountered during the period of the Dot-Com crisis indicates decoupling of Latin American stock markets with respect to the United States stock markets. This occurred because a period of crisis in the United States coincided with a period in which the major Latin American stock markets were recovering from idiosyncratic and regional crises experienced during the late 1990s. Regulators at Latin American countries imposed several protectionist measures that isolated the effects of the Dot-Com crisis to regional markets in Latin America.

During the last two crisis, however, there is evidence of contagion provided by the fact that dynamic correlations between markets in Latin America and the S&P 500 increased significantly. The recent crises experienced by developed economies transmitted mainly through financial channels to emerging market economies, including those considered in this study. However, the effects of these two financial crises on Latin American countries were partially different. The subprime crisis affected the most Peru and Mexico. Meanwhile, the European crisis affected mostly Colombia and Peru.

4. Conclusions

This study uses Dynamic Conditional Correlation multivariate GARCH approach for testing for contagion among Latin American financial markets to shocks originated in the United States and Europe.

We follow Forbes and Rigobon (2002), who define contagion in terms of significant increases in international cross-market linkages following the occurrence of a shock to one country. In this sense, contagion relates to the behavior of market interdependence after the happening of a shock.

Our focus is on studying the propagation of shocks originated in the United States stock market to the stock markets of the six major Latin American countries. We use daily stock market data for the period comprised between July 4th , 2001 and December 30th , 2014, and apply the Dynamic Conditional Correlation (DCC) multivariate GARCH model of Engle (2002) for identifying periods of contagion between pairs of markets.

Our results show there are statistically significant increases in conditional correlations between the stock markets of most of the Latin American countries considered in this study during two periods. The first, comprised between 2007 and 2009, corresponding to the subprime international financial crisis. The second, between 2011 and 2012, corresponds to the recent European sovereign bond crisis. These findings go in line with those obtained by Syllignakis and Kouretas (2011), who identify an episode of contagion in Central and Eastern European markets originated in the United States subprime crisis of 2007-09.

Our contributions to the literature are two-folded. First, this study is, up to our knowledge, the first in focusing in Latin American economies in testing for contagion after the occurrence of an external negative shock, using a sample period which covers three major external financial crises. Second, it is also the first to study the effects of both the subprime mortgage crisis in the United States and the more recent sovereign European bond crisis in a set of emerging economies.

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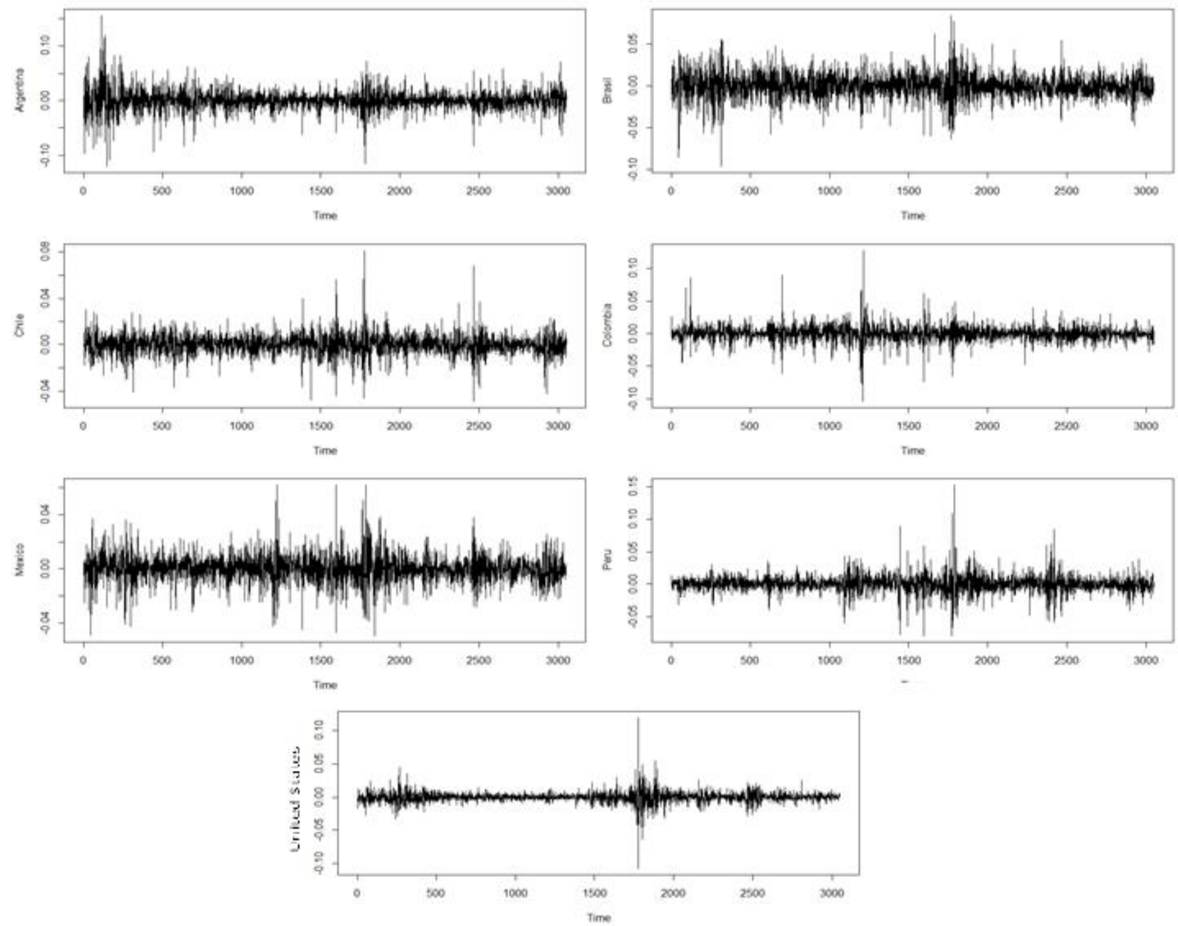
Appendix A

Returns Graphs



Appendix B

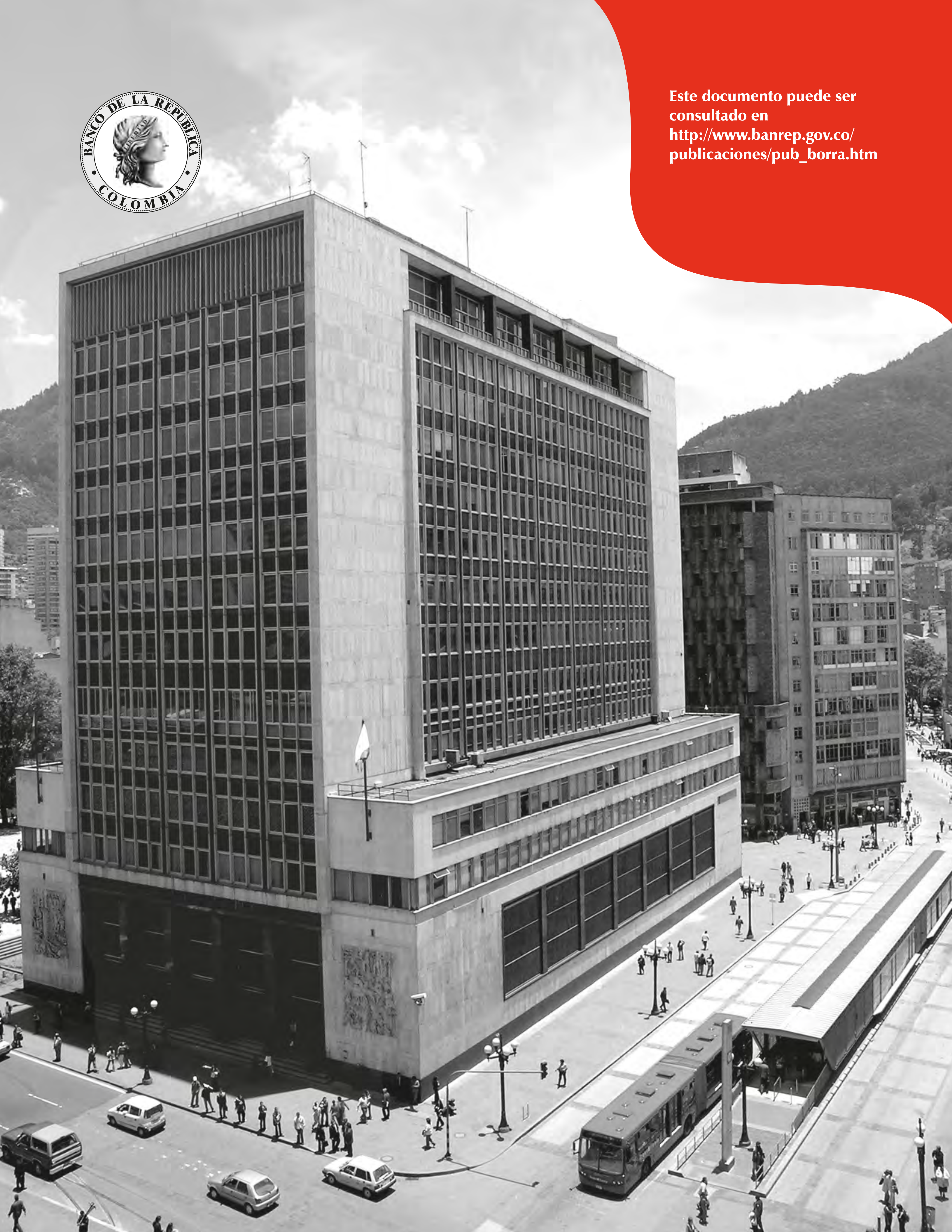
LM Test on Standardized Residuals

LM Test - Edgerton-Shukur				
Lags	**F Statistic**	**DF1**	**DF2**	**p-value**
200	1.0225	9800	10577	0.1309

Appendix C

LM Test on Squared Standardized Residuals

LM Test - Edgerton-Shukur				
Lags	**F Statistic**	**DF1**	**DF2**	**p-value**
25	1.0822	1225	20062	0.02671



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