Economics Bulletin

Volume 31, Issue 2

Risk transmission between Latin America stock markets and the US: impacts of the 2007/2008 Crisis

Fernanda G Barba
Universidade Federal de Santa Maria

Paulo S Ceretta
Universidade Federal de Santa Maria

Abstract

The aim of this paper is to investigate whether the US subprime financial turmoil has had any statistically significant effect on the conditional volatility of stock prices in Latin America for which the BEKK methodology is adopted, developed by Engle and Kroner (1995). The t-student distribution is employed as it can provide a best fit for financial data. In order to do this study, we will investigate four Latin America emerging capital markets (Brazil, Argentina, Chile and Mexico) and the United States, considering the period of the recent financial crisis of 2007/2008, analyzing before, during and after the crisis period. Our results show that before the crisis there is no evidence of volatility spillovers from the North American stock market to Latin American ones. During the crisis, there is evidence of volatility spillover effects on some countries. Brazil and Chile affect the US volatility and Argentina, Chile and Mexico are affected by the US's. After the crisis, the volatility of all Latin American stock markets affect and are affected by the US market. These results show an increase in spillover effects from a shock to US stock market to Latin American countries after the 2007/2008 financial crisis.

Citation: Fernanda G Barba and Paulo S Ceretta, (2011) "Risk transmission between Latin America stock markets and the US: impacts of the 2007/2008 Crisis", *Economics Bulletin*, Vol. 31 no.2 pp. 1025-1037.
Submitted: Feb 16 2011. **Published:** April 02, 2011.

1 Introduction

The 2007-2008 subprime crisis has raised once more the interest on international market integration. In the era of global markets and global investing, this crisis has challenged investors' recently gained perceptions about equity investing. The crisis has driven down equity levels across the globe, and in nearly every country, sector and industry. As a result some investors have been questioning previously held beliefs about the risk of equity investing and the benefits of global diversification (Bartram and Bodnar, 2009).

Events of global importance tend to have a significant impact on the world's stock markets. Financial markets crises can lead to dramatic changes in investment behavior and so it is important to study the dynamic interdependence of stock markets before and after any significant economic shock (Edwards, 2000). Empirical studies show that the comovement patterns of national stock markets change significantly after major economic events like crises. Some authors have evidenced that comovement or cointegration among stock markets of other countries increases drastically during the crisis (Granger and Morgenstern, 1970; Arshanapalli *et al.*, 1995; Malliaris and Urrutia, 1992; Hon, Strauss and Yong, 2006; Khalid and Rajaguru, 2007; Huyghebaert and Wang, 2010).

The increasing interest and motivation on studying volatility can be explained by various reasons, but the most relevant of all include the international portfolio diversification issues and the recurrence of financial crises that occurred in both developed and emerging countries during the 1990's decade. (Arouri, Bellalah, & Nguyen, 2008). Kyle (1985) has pointed out that much of the information is revealed in the volatility of stock prices, more than in the price itself. The volatility of equity and stock market prices is usually viewed as an indicator of vulnerability for the different segments of financial markets and over the last ten years, the volatility of Latin American financial markets has become a key determinant for explaining the risk-taking behaviors of investors, especially the substitution in their portfolios between different categories of securities (corporate and government bonds) (Dufrenot, Mignon & Péguin-Feissolle, 2010).

A number of theoretical and empirical studies have employed a wide variety of methods and data frequencies to model the comovement of international stock markets and searched for the reasons behind this phenomenon. The focus has been mostly on the correlations and the stock return and volatility spillovers between stock markets around the world (Arouri, Bellabah and Nguyen, 2008). Despite a large body of literature on international market interdependence, the existing empirical evidence remains ambiguous and has yielded conflicting results regarding the nature of the dynamic interdependence among developed and/or emerging markets (Awokuse, Chopra e Bessler, 2009).

The aim of this paper is to investigate whether the US subprime financial turmoil has had any statistically significant effect on the conditional volatility of stock prices in Latin America for which the BEKK methodology is adopted, developed by Engle and Kroner (1995). The t-student distribution is employed as it can provide a best fit for financial data. In order to do this study, we will investigate four Latin America emerging capital markets (Brazil, Argentina, Chile and Mexico) and the United States, considering the period of the recent financial crisis of 2007/2008, analyzing before, during and after the crisis period. These Latin American emerging markets rank among the most mature markets within the universe of emerging countries and they actually attract a particular attention from global investors thanks to their great market openness (Arouri *et al.*, 2009).

The remainder of the paper is organized as follows. Section 2 presents a brief literature review on stock market linkages and financial crisis; Section 3 presents the data and the econometric methodology; Section 4 discusses the empirical results; and Section 5 outlines the conclusions.

2 Stock market linkages and financial crisis

There is a widespread interest in understanding the extent to which the increasing interdependencies in trade and financial linkages among countries in recent years contributed to spillover effects from the United States to other countries (Angkinand, Barth and Kim, 2009).

The issue of equity market comovement in Latin America has been investigated by several studies (Arouri *et al.*, 2008). Choudry (1997) employs unit root tests, cointegration tests and error correction models to examine the long-run relationship between six Latin American markets and the US market, and finds evidence of cointegration relationship and significant causality among these markets. Christofi and Pericli (1999) show evidence of significant cross-market linkages in five Latin American markets (Argentina, Brazil, Chile, Colombia and Mexico) from combining a vector autoregressive (VAR) model with a multivariate exponential GARCH process. They find a statistically significant linkage between eight equity markets of the Americas and the US stock market.

Collins and Gavron (2005) conducted 44 events of contagion in 42 countries and found that the Brazilian and Argentinean crisis generated most of the contagion events. Their results suggest that incidences of contagion were not more frequent within the trade blocks compared to with countries outside them. The authors found that the most vulnerable countries to contagion were the smaller, less mature in other areas, suggesting that regional and trade links do not necessarily predispose a country to experiencing contagion from its neighbors.

Arouri *et al.* (2008) analyze the time-variations of conditional correlations between Latin American emerging markets and between them and the World stock market. The cross market correlation was empirically estimated from a DCC-GARCH model. The data used are on a monthly basis, over the period of January 1985 to August 2005. The Latin American markets studied are Argentina, Brazil, Chile, Colombia, Mexico and Venezuela. Their findings indicate a clear upward trend in correlation from 1994 and onwards as a result of market liberalization and increased globalization. There are sudden increases in conditional correlation following the Asian and Brazilian financial crises in 1997-1998 and, to less extent, the stock market crash in 1987 and the Latin American markets crises in 1994 and 2001. They also confirm in their study that the inter-market comovements were significantly higher during the crisis period than during the tranquil period.

Bellotti and Williams (2010) tried to identify significant cross-border volatility transmission or spillover effects across emerging markets during four time intervals that proxy for distinct changes in government policy and equity market structure; financial sector booms; financial crisis and recovery. The amount of spillover effects in Latin America appears not to have changed. The empirical evidence suggests equity market interdependencies increase during episodes of financial crisis especially in Asia.

Beirne *et al.* (2010) examined volatility spillovers running from mature to emerging stock markets. They employed a tri-variate VAR-GARCH framework with the BEKK representation proposed by Engle and Kroner (1995) to model the means and variances of stock returns in local, regional, and mature markets, with the latter defined as a weighted average of the US, Japan, and Europe (Germany, France, Italy, and the UK). They concluded that spillovers from mature markets do influence the dynamics of conditional variances of returns in many local and regional emerging stock markets.

Lahrech and Sylwester (2008) tried to find out whether there has been a structural change in the bivariate correlations between the US and Latin American equity returns during the period spanning from 1988 to 2004. Results show an increase in the degree of market

integration between these countries and the United States. The beginning of rapid integration coincides with the beginning of liberalization for Argentina and Brazil. For Mexico and Chile they find that the period of rapid integration is within the period of increasing bilateral trade. Chile has the lowest correlations with the US.

Diamandis (2009) provides an analysis on the issue of international financial linkages by examining the existence of common stochastic trends between four Latin America emerging capital markets (Argentina, Brazil, Chile and Mexico) and the US. The analysis was carried out by estimating the autoregressive and moving average representation of a cointegration system. This study achieved four main results: 1) the four Latin America emerging stock markets and the mature US market are partially integrated; 2) the five stock markets have four significant common permanent components which drive their system in the long run; 3) the Latin America markets are more influenced by, and contribute more, to the common trends than the US market; and 4) there were significant short-run deviations from the common stochastic trends during the 1994-1996 Mexican crisis and the 2001 financial crisis which were documented for all markets under investigation. These transitory deviations are short-lived.

Didier, Love and Pería (2010) investigated the factors that determine stock markets' vulnerability to the 2007-2008 crises across 83 countries. They evaluated the extent to which the comovement in stock market returns was driven by real linkages between economies, financial linkages across markets, or was the consequence of a "wake-up call" or "demonstration effect" where investors became aware that certain vulnerabilities present in the US context could put other economies at risk. They used stock market data between July 2007 and April 2009 and followed a one-step approach in which each markets' correlation vis-à-vis the US market is interacted with country-level characteristics representing the channels of transmission. The authors found that the main channel of transmission was financial, they also found evidence of a wake-up in the first stage of the crisis. Furthermore, markets with high ratios of equity holdings by US investors exhibited greater comovement. Their results also highlight the dark side of financial integration and liquidity since countries that are more integrated and have more liquid markets experienced greater comovement with the US.

Yiu, Ho and Jin (2010) investigated the spillover of financial crisis by studying the dynamics of correlation between eleven Asian and six Latin American stock markets vis-à-vis the US stock market. They used weekly returns of the two regional stock markets and that of the US stock market from February 1993 to March 2009 by adopting a two-step approach. First they used principal component analysis to extract the major driving force behind the eleven Asian equity markets (also the six Latins American equity markets) and then estimate the dynamic conditional correlation between this driving force and the US equity market. The volatility correlation between the US financial market and Asian financial markets as well as the volatility correlation between the US financial market and the Latin American financial markets are positive and jump up substantially during the recent financial crisis originating from the US. This, therefore, shows evidence of financial contagion in the international dimension during the crisis period.

Naoui, Liouane and Brahim (2010) examined contagion phenomenon as induced by the subprime crisis that started in 2007 in the American risk-based mortgage market and which spread worldwide. Daily returns of stock price indices from January 2, 2006 through February 26, 2010, were used for six developed market and ten emerging markets (US, France, Germany, Netherlands, UK, Italy, India, Hong Kong, Malaysia, Korea, China, Singapore, Brazil, Mexico, Argentina and Tunisia). First they examined the simple correlation between the American market and other European and emerging markets before and after the crisis. Then they refine their analysis through estimating the dynamic

conditional correlation model developed by Engle. It is almost clear that by the end of the crisis correlations considerably increased to exceed 80% for all developed countries. The results allowed them to classify these countries into three groups. The first includes three countries with high conditional correlation with the American market during the crisis, namely Brazil, Mexico and Argentina.

Dufrenot, Mignon and Péguin-Feissolle (2010) concentrate on the financial linkage and examine empirically the link between the US subprime crisis and the volatility of the Latin American countries (LAC) equity and stock markets. Their sample consisted of five countries that are classified as those with the most matured financial markets in Latin America and also the most integrated with the world financial markets: Brazil, Chile, Colombia, Mexico, and Peru. They used a time-varying transition probability Markov-switching model (TVPMS). Considering daily data from 2004 to mid 2009, they found that financial stress was transmitted from the US market to the LAC's equity market volatility. Their estimations show that a broad range of stress indicators in the US financial market can cause abrupt changes in the volatility of the LAC equity and stock markets. Mexico is the most vulnerable to the US financial stress, since this country has the closer links with the US financial markets. A similar conclusion holds for Chile, although not all the transition variables were statistically significant. The other countries seem to be much more sensible to the activity in the regional financial markets (Colombia, Peru and Brazil).

Barba and Ceretta (2010) investigated the potential time-varying behavior of long-run stock market relationships among Latin American countries and the United States employing the Engle-Granger methodology. They investigated four Latin American emerging capital markets (Brazil, Argentina, Chile and Mexico) and the United States, considering the period of the recent financial crisis of 2007/2008, testing for co-integration before, during and after the crisis period. Their results show that Latin American equity markets seem to respond differently to shocks in the US stock markets in the long-run. The relationships between two Latin American countries - Argentina and Brazil - and the United States have changed over time, becoming more integrated. Chile's and Mexico's relationships with the US did not suffer a significant change during or after the crisis period. Their findings show that Latin America does not respond homogenously to US shocks. This information provides evidence that, for international diversification, each country should be analyzed individually. Analyzing Latin America as a group could lead to mistaken conclusions about international diversification opportunities.

3 Data and econometric methodology

In this section we present the data used and describe the methodology employed in this paper.

3.1 Data description

The data used in this study consist of the daily closing index price of four Latin American markets – Bovespa (Brazil), Merval (Argentina), Bolsa Mexicana de Valores (Mexico), Bolsa de Santiago (Chile) – and the Dow Jones index for the United States.

The sample period is from January 2, 2006 to August 31, 2010. The sample was fractioned into three subsamples as follows: *prior to the 2007-2008 crisis* (from January 2, 2006 to August 8, 2007), *during the 2007-2008 crisis* (from August 9, 2007 to October 27, 2008) and *after the 2007-2008 crisis* (from October 28, 2008 to August 31, 2010). The dating of the crisis period is based on the dates suggested by Baba and Packer (2009). The series had some missing observations at different points of time as the holidays may differ among countries. It was used the value of the previous day to fill in the gaps.

Table 1
Market capitalization of listed companies (in millions of current US$)

Country	2005	2006	2007	2008	2009
Argentina	$61,477.59	$79,730.41	$86,684.20	$52,309.39	$48,033.12
% of GDP	33.6	37.2	33.0	15.9	15.8
Brazil	$474,647.00	$711,100.00	$1,370,380.00	$589,384.00	$1,337,720.00
% of GDP	53.8	65.3	100.3	36.0	74.3
Chile	$136,446.00	$174,556.00	$212,910.00	$132,428.00	$230,732.00
% of GDP	115.4	118.9	129.6	77.5	128.0
Mexico	$239,128.00	$348,345.00	$397,725.00	$232,581.00	$352,045.00
% of GDP	28.2	36.6	38.8	21.3	38.9
United States	$16,970,900.00	$19,425,900.00	$19,947,300.00	$11,737,600.00	$15,077,300.00
% of GDP	134.9	145.7	142.4	81.7	105.8

Source: World Bank.

Table 1 presents the market capitalization of listed companies of each country from 2005 to 2009 and the market capitalization in percentage of GDP from 2005 to 2008. Market capitalization (also known as market value) is the share price times the number of shares outstanding. Listed domestic companies are the domestically incorporated companies listed on the country's stock exchanges at the end of the year. Listed companies does not include investment companies, mutual funds, or other collective investment vehicles (World Bank). The market capitalization of shares listed on the Brazilian stock exchange is the largest among the Latin American countries. At the end of 2009 it exceeded US$ 1.3 trillion, a growth of more than three times its value in 2005. Argentina has the smallest market capitalization, of US$ 48 billion, around 22% less than its value in 2005. While Chile and Mexico grew about 70% and 50%, respectively, from 2005 to 2005, Brazil grew more than 180% in the same period. Compared to the United States, these markets are still very small. The US market capitalization at the end of 2009 was over US$ 15 trillion. The United States has the largest market capitalization in percentage of GDP in all periods followed by Chile.

In Table 2 we present the foreign direct investment from 2005 to 2008 in the countries analyzed. Foreign direct investment are the net inflows of investment to acquire a lasting management interest (10 percent or more of voting stock) in an enterprise operating in an economy other than that of the investor. It is the sum of equity capital, reinvestment of earnings, other long-term capital, and short-term capital as shown in the balance of payments. This series shows net inflows (new investment inflows less disinvestment) in the reporting economy from foreign investors (World Bank). Once more, Brazil had the largest growth in the period, of more than 200%. This growth shows an increasing level of confidence on the Brazilian economy.

Table 2
Foreign direct investment, net inflows (BoP, in thousands of current US$)

	2005	2006	2007	2008
Argentina	5,265,263.18	5,537,340.00	6,473,150.00	9,752,902.87
Brazil	15,066,291.74	18,782,215.42	34,584,901.03	45,058,156.30
Chile	6,983,801.37	7,298,382.45	12,577,182.,85	16,786,870.00
Mexico	21,976,700.00	19,428,100.00	27,527,900.00	22,481,100.00
United States	112,638,000.00	243,151,000.00	275,758,000.00	319,737,000.00

Source: World Bank.

Table 3
Summary statistics of daily returns (log difference of the price).

	Argentina	Brazil	Chile	Mexico	US
Panel A. Before 2007/2008 crisis					
Nobs	414	414	414	414	414
Minimum	-0.07787	-0.06857	-0.05099	-0.05978	-0.03305
Maximum	0.06086	0.04846	0.02960	0.06510	0.02427
Range	0.13873	0.11702	0.08058	0.12488	0.05731
1 Quartile	-0.00530	-0.00663	-0.00294	-0.00605	-0.00342
3 Quartile	0.00898	0.01039	0.00630	0.00881	0.00510
Mean	0.00081	0.00121	0.00125	0.00131	0.00054
Median	0.00102	0.00107	0.00157	0.00230	0.00070
Variance	0.00019	0.00023	0.00008	0.00018	0.00006
Standard deviation	0.01373	0.01502	0.00891	0.01345	0.00768
Skewness	-0.61503	-0.31817	-1.11796	-0.14347	-0.49768
Kurtosis	3.67276	1.74354	5.75111	2.87801	1.78135
Panel B. During 2007/2008 crisis					
Nobs	313	313	313	313	313
Minimum	-0.12952	-0.12096	-0.06215	-0.07266	-0.08695
Maximum	0.10432	0.13677	0.11803	0.10441	0.10089
Range	0.23383	0.25773	0.18018	0.17707	0.18784
1 Quartile	-0.01011	-0.01536	-0.00871	-0.01028	-0.00970
3 Quartile	0.00736	0.01267	0.00694	0.00748	0.00670
Mean	-0.00291	-0.00191	-0.00102	-0.00182	-0.00137
Median	0.00000	0.00029	0.00000	-0.00075	-0.00034
Variance	0.00054	0.00074	0.00030	0.00035	0.00031
Standard deviation	0.02326	0.02716	0.01725	0.01875	0.01766
Skewness	-1.14749	-0.19957	0.64222	0.10438	-0.09580
Kurtosis	7.91878	4.27750	8.19457	4.46378	5.82350
Panel C. After 2007/2008 crisis					
nobs	474	474	474	474	474
Minimum	-0.07700	-0.08067	-0.03627	-0.05962	-0.08120
Maximum	0.08431	0.08985	0.03212	0.06767	0.06480
Range	0.16131	0.17053	0.06839	0.12730	0.14600
1 Quartile	-0.00712	-0.00780	-0.00375	-0.00573	-0.00745
3 Quartile	0.01248	0.01024	0.00664	0.00819	0.00827
Mean	0.00203	0.00141	0.00135	0.00112	0.00021
Median	0.00124	0.00084	0.00152	0.00134	0.00053
Variance	0.00046	0.00039	0.00010	0.00026	0.00030
Standard deviation	0.02142	0.01985	0.00982	0.01615	0.01718
Skewness	-0.11331	0.20293	-0.23582	0.15528	-0.27862
Kurtosis	1.80569	2.87669	1.52270	2.60098	2.60836

The summary statistics of the log difference of the price is given in Table 3. Before the crisis, Argentina reached the lowest return and the largest range as well as the highest standard deviation. Mexico reached the highest return and also had the highest mean. The US had the smallest range. All series presented negative skewness. During the crisis, both the range and standard deviation of returns of all countries were larger than before this period. The mean was negative to all countries, suggesting that the environment during the period of

crisis brought down the returns associated to a higher risk. After the crisis the maximum reached values higher than before it. The standard deviation is lower than during the crisis period, but still higher than before the crisis. The means are all positive. Brazil has the largest range during and after the crisis.

3.2 Multivariate GARCH

In order to analyze the volatility spillover effect we use a multivariate GARCH model. Specifically we use the BEKK model proposed by Engle and Kroner (1995). According to Wang (2009), the BEKK model can be written as

$$\mathrm{H_t} = \mathrm{A_0 A_0^{'}} + \mathrm{A_i^{'}} \varepsilon_{\mathrm{t-i}} \varepsilon_{\mathrm{t-i}}^{'} \mathrm{A_i} + \mathrm{B_j^{'}} \mathrm{H_{t-j}} \mathrm{B_j}, \quad (1)$$

Where $\mathrm{A_0}$ is a symmetric $(N \times N)$ parameter matrix, and $\mathrm{A_i}$ and $\mathrm{B_j}$ are unrestricted $(N \times N)$ parameter matrix. This specification allows the conditional variances and covariances of the time series to influence each other, and at the same time, does not require to estimate a large number of parameters. (Wang, 2009) Based on the symmetric parameterization of the model, $\mathrm{H_t}$ is almost surely positive definite provided that $\mathrm{A_0 A_0^{'}}$ is positive definite (Tsay, 2010). Wang (2009) writes the variances and covariances explicitly as:

$$h_{11,t} = \alpha_{11,0} + \left(\alpha_{11,1}^2 \varepsilon_{1,t-1}^2 + 2\alpha_{11,1}\alpha_{21,1}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + \alpha_{21,1}^2 \varepsilon_{2,t-1}^2\right) + \left(\beta_{11,1}^2 h_{11,t-1} + 2\beta_{11,1}\beta_{21,1} h_{12,t-1} + \beta_{21,1}^2 h_{22,t-1}\right), \quad (2)$$

$$h_{12,t} = h_{21,t} = \alpha_{12,0} + \left[\alpha_{11,1}\alpha_{12,1}\varepsilon_{1,t-1}^2 + \left(\alpha_{12,1}\alpha_{21,1} + \alpha_{11,1}\alpha_{22,1}\right)\varepsilon_{1,t-1}\varepsilon_{2,t-1} + \alpha_{21,1}\alpha_{22,1}\varepsilon_{2,t-1}^2\right] + \left[\beta_{11,1}\beta_{21,1} h_{11,t-1} + \left(\beta_{12,1}\beta_{21,1} + \beta_{11,1}\beta_{22,1}\right) h_{12,t-1} + \beta_{21,1}\beta_{22,1} h_{22,t-1}\right], \quad (3)$$

$$h_{22,t} = \alpha_{22,0} + \left(\alpha_{12,1}^2 \varepsilon_{1,t-1}^2 + 2\alpha_{12,1}\alpha_{22,1}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + \alpha_{22,1}^2 \varepsilon_{2,t-1}^2\right) + \left(\beta_{12,1}^2 h_{11,t-1} + 2\beta_{12,1}\beta_{22,1} h_{12,t-1} + \beta_{22,1}^2 h_{22,t-1}\right), \quad (4)$$

The diagonal elements of the matrix, h_{11} and h_{22}, evaluate the impact of the shock in one series on the volatility of the other. This impact could be asymmetric or only be one way effective (Wang, 2009). The parameters $\alpha_{11,1}$ and $\alpha_{22,1}$ represent the effect of the shock on the future uncertainty of the same time series and $\alpha_{21,1}$ and $\alpha_{12,1}$ represent the cross effect. If $\alpha_{11,1}$ and $\alpha_{21,1}$ have different signs, then the shocks with different signs in the two time series tend to increase the future uncertainty in the first time series. In the same way, if $\alpha_{12,1}$ and $\alpha_{22,1}$ have different signs, the future uncertainty of the second time series might increase if the two shocks have different signs (Wang, 2009).

4 Empirical results

In order to analyze the volatility spillover effect of the 2007/2008 crisis in the Latin American stock markets we first calculated the daily returns of the stock indices by the first difference of the natural logarithm. We then filtered the serial dependence of the series with an Autoregressive Vector. The BEKK model was then estimated using a t-student distribution

for Argentina/US, Brazil/US, Chile/US and Mexico/US for the periods before, during and after the 2007/2008 crisis.

Table 4
Estimated coefficients for the BEKK model considering a t-student distribution before the 2007/2008 crisis.

	Argentina	Brazil	Chile	Mexico
C(1,1)	0.00278**	-0.00417**	0.00163**	-0.00364**
C(2,1)	0.00030	-0.00015	-0.00014	0.00052
C(2,2)	-0.00074	0.00045	0.00000	0.00239
A(1,1)	0.31386**	0.27707**	0.34981**	0.44681**
A(1,2)	0.05602	-0.00044	0.07825	0.12393*
A(2,1)	-0.15464	0.02860	-0.09555	-0.29490*
A(2,2)	0.14885*	0.18474**	-0.13409*	-0.29741**
B(1,1)	0.92336**	0.89113**	0.92242**	0.82150**
B(1,2)	-0.01425	0.01062	0.03154	0.07619
B(2,1)	0.04184	0.06924	0.00757	0.15586
B(2,2)	0.98529**	0.96886**	0.97662**	0.82663**
Shape	6.48638**	6.20999**	7.69884**	7.55318**
Log Likelihood	2895.69	2724.93	2873.88	2728.94
Ljung-Box of residuals	3,0178 (0,697)	0,4813 (0,993)	3,3174 (0,651)	0,6994 (0,983)
Ljung-Box of squared residuals	0,4052 (0,995)	2,0157 (0,847)	4,6374 (0,462)	0,6398 (0,986)
Ljung-Box of residuals (US)	5,5567 (0,352)	0,2348 (0,999)	0,5906 (0,988)	0,7486 (0,980)
Ljung-Box of squared residuals (US)	0,7122 (0,982)	0,5323 (0,991)	1,4796 (0,915)	2,0720 (0,839)

Significance level: ** 1%, * 5%
Note: The values in the brackets are probability values. The Ljung-Box Q statistic was estimated with a lag 5.

Table 4 presents the estimated coefficients for the BEKK model considering a t-student distribution before the 2007/2008 crisis. The coefficients A(1,1) and A(2,2) are significant for all indices meaning that all indices are affected by their own index news shocks. Also the coefficients B(1,1) and B(2,2) presented a significance level of 1% for all indexes which means that all indices are affected by their own conditional volatility. The off diagonal parameters A(1,2), A(2,1) were only significant to Mexico, and the parameters B(1,2) and B(2,1) were not significant before the crisis for any of the countries. In other words, there is no evidence of volatility spillover effect between any of these Latin American countries and the US before the crisis. Analyzing Mexico specifically, the coefficients A(1,1) and A(2,1) have different signs, the same happens to the coefficients A(1,2) and A(2,2). According to Wang (2009) that means that the shocks tend to increase the future uncertainty in the Mexican and North American markets.

In Table 5 we report the estimated coefficients for the BEKK model considering a t-student distribution during the 2007/2008 crisis. Similarly to the period before the crisis, Brazil, Chile and Mexico are affected by their own shocks during the crisis. There is evidence of shocks from Argentina affecting the US and vice-versa. Chile is also affected by shocks from the US. Argentina, Brazil and Chile are affected by their own conditional volatility. The volatility spillover effect starts to appear during the crisis period. Argentina, Chile and Mexico are affected by the conditional volatility of the US and Brazil and Chile's conditional volatility affect the US's. The Ljung-Box Q statistic for the squared residual of the US, in the model considering its relationship with Chile, was significant, which could mean that the financial crisis might have changed the structure of the relationship between these countries and the BEKK model could not fully capture this change of behavior.

Table 5
Estimated coefficients for the BEKK model considering a t-student distribution during the 2007/2008 crisis.

	Argentina	Brazil	Chile	Mexico
C(1,1)	-0.00208	0.00532**	-0.00017	0.01058**
C(2,1)	0.00176*	-0.00360**	-0.00485**	0.00151
C(2,2)	0.00000	0.00000	0.00346**	0.00000
A(1,1)	0.12220	0.44463**	0.14611*	0.31743**
A(1,2)	-0.16640**	-0.07066	-0.14169	-0.03217
A(2,1)	-0.50916**	-0.26075	0.25475**	0.18815
A(2,2)	0.05979	0.18714	0.08969	0.28842**
B(1,1)	0.86444**	0.85723**	1.01783**	0.12011
B(1,2)	-0.01771	0.17639**	0.30323**	0.19806
B(2,1)	0.12967**	0.12599	-0.15134*	0.51721*
B(2,2)	0.98850**	0.74773**	0.71087**	0.80164**
Shape	13.02057*	15.00911	23.61918	11.50490*
Log Likelihood	1671.93	1643.54	1823.41	1770.61
Ljung-Box of residuals	1,199 (0,945)	3,540 (0,617)	1,684 (0,891)	0,345 (0,997)
Ljung-Box of squared residuals	3,046 (0,693)	4,856 (0,434)	4,285 (0,509)	1,554 (0,907)
Ljung-Box of residuals (US)	1,438 (0,920)	2,387 (0,793)	1,869 (0,867)	2,687 (0,748)
Ljung-Box of squared residuals (US)	7,819 (0,166)	5,010 (0,415)	14,733 (0,012)	8,724 (0,121)

Significance level: ** 1%, * 5%
Note: The values in the brackets are probability values. The Ljung-Box Q statistic was estimated with a lag 5.

Table 6
Estimated coefficients for the BEKK model considering a t-student distribution after the 2007/2008 crisis.

	Argentina	Brazil	Chile	Mexico
C(1,1)	0.00614**	0.00950**	0.00709**	0.00314**
C(2,1)	0.00210**	0.00255**	0.00202*	0.00132
C(2,2)	0.00000	0.00000	0.00000	0.00000
A(1,1)	-0.20010	0.72140**	-0.17171	0.25128*
A(1,2)	-0.04235	0.30439**	-0.08438	0.24365**
A(2,1)	0.00648	-0.74098**	0.03341	-0.23401*
A(2,2)	0.25361**	-0.07492	0.30484**	0.04389
B(1,1)	0.77228**	0.35959	0.24469	0.77436**
B(1,2)	-0.12141**	-0.24427**	-0.35492**	-0.17387**
B(2,1)	0.28215**	0.45079**	0.24161*	0.21006**
B(2,2)	1.05652**	1.12542**	1.05829**	1.07621**
Shape	6.40436**	8.28189**	9.93306**	6.66747**
Log Likelihood	2674.31	2792.46	2994.85	2895.69
Ljung-Box of residuals	4,528 (0,476)	6,626 (0,250)	0,773 (0,979)	4,140 (0,529)
Ljung-Box of squared residuals	15,733 (0,008)	3,931 (0,559)	13,350 (0,020)	5,819 (0,324)
Ljung-Box of residuals (US)	1,604 (0,901)	1,492 (0,914)	2,554 (0,768)	5,497 (0,358)
Ljung-Box of squared residuals (US)	6,678 (0,246)	6,851 (0,232)	9,752 (0,083)	7,470 (0,188)

Significance level: ** 1%, * 5%
Note: The values in the brackets are probability values. The Ljung-Box Q statistic was estimated with a lag 5.

The coefficients estimated for the BEKK model considering a t-student distribution after the 2007/2008 crisis are presented in Table 6. In this period, only Brazil and Mexico respond to their own shocks and conditional volatility. These two countries are also the only ones that affect and are affected by US shocks. On the other hand, all countries respond and influence the conditional volatility of the US. Brazil has significant A(1,1) and A(2,1)

coefficients with different signs meaning that the shocks tend to increase the future uncertainty in the Brazilian market. The Ljung-Box Q statistic for the squared residual of Argentina and Chile were significant. Once again, this could mean that the financial crisis might have changed the structure of these countries and the BEKK model could not fully capture this change.

5 Conclusions

In this paper we attempted to investigate the volatility spillover effects of the US stock market on Latin American markets before, during and after the 2007/2008 crisis period. For such we employed a BEKK model considering a t-student distribution for each period of time.

Our results show that before the crisis there is no evidence of volatility spillovers from the North American stock market to Latin American ones. During the crisis, there is evidence of volatility spillover effects on some countries. Brazil and Chile affect the US volatility and Argentina, Chile and Mexico are affected by the US's. After the crisis, the volatility of all Latin American stock markets affect and are affected by the US market.

These results show an increase in spillover effects from a shock to US stock market to Latin American countries after the 2007/2008 financial crisis. This finding is supported by the literature which confirms that financial crisis increase market integration. We also find that, differently to the results obtained by Barba and Ceretta (2010), the relationship between Latin American markets and the US seem to change over time quite homogeneously as before the crisis none of the Latin American markets presented volatility spillover effects and after the crisis, all of them presented this effect. This confirms what Angkinand, Barth and Kim (2009) concluded in their study on the effects of the subprime crisis on developed countries.

Our findings suggest that the degree of integration among countries tend to change over time, especially around periods marked by financial crisis. This increase in the spillover effect between the US and Latin American stock markets after the 2007/2008 crisis could mean that equity market disturbances in US are rapidly transmitted to these countries. For policy makers, these results suggest that Latin American countries could be more susceptible to risk transmission from the US after a financial crisis in the latter.

References

Angkinand, A., Barth, J. and Kim, H. (2010) "Spillover effects from the US financial crisis: some time-series evidence from national stock returns" *Forthcoming: The Financial and Economic Crisis: An International Perspective*, Benton Gup Editor.

Arouri, M.; Bellalah, M.; Nguyen, D.K. (2008) "The comovements in international stock markets: new evidence from Latin American emerging countries" ISC Paris School of Management Working Paper n. halshs-00202943.

Arshanapalli, A., Doukas, J., Lang, L.H.P. (1995) "Pre- and post-October 1987 stock market linkages between US and Asian markets" *Pacific-Basin Finance Journal* **3**, 57–73.

Awokuse, T. O.; Chopra, A.; Bessler, D. A. (2009) "Structural change and international stock market interdependence: evidence from Asian emerging markets" *Economic Modelling* **26**, p. 549-559.

Baba, N., Packer, F. (2009) "Interpreting deviations from covered interest parity during the financial market turmoil of 2007-08" *Journal of Banking and Finance* **33**, 1953-1962.

Barba, F., Ceretta, P. (2010) "Long-Run Relationship Among Latin America Stock Markets and the US - Impacts of the 2007/2008 Crisis" Working Paper. Available in: <http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1697732>.

Bartram, S., Bodnar, G. (2009) “No place to hide: the global crisis in equity markets in 2008/2009” *Journal of International Money and Finance* **28**, 1246-1292.

Beirne, J., Caporale, G., Schulze-Ghattas, M, Spagnolo, N. (2010) “Global and regional spillovers in emerging stock markets: a multivariate GARCH-in-mean analysis” *Emerging Markets Review* **11**, 205-260.

Bellotti, X., Williams, J. (2010) “Time varying volatility transmission: the case of emerging equity markets in Asia and Latin America, 1984-2004” Working paper. Available in: <http://eprints.mdx.ac.uk/4069/1/Time_Varying_2004.pdf>

Boschi, M. (2005) “International financial contagion: evidence from the argentine crisis of 2001-2002” *Applied Financial Economics* **15** (3), 153-163.

Chen, G., Firth, M., Rui, O. (2002) “Stock market linkages: evidence from Latin America” *Journal of Banking & Finance* **26**, 1113-1141.

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.

Collins, D. and Gavron, S. (2005) “Measuring Equity Market Contagion in Multiple Financial Events” *Applied Financial Economics,* **15**(8).

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

Didier,T., Love, I., Pería, M. S. (2010) “What explains stock market’s vulnerability to the 2007-2008 crisis?” World Bank policy research working paper 5224.

Dufrenot, G., Mignon, V., Peguin-Feissolle, A. (2010) “The effects of the subprime crisis on the latin american financial markets: an empirical assessment” Working Papers 2010-11, CEPII research center.

Engle, R., Kroner, K. (1995) “Multivariate Simultaneous Generalized ARCH” *Econometric Theory* **11**,122-150.

Edwards, S. (2000) Contagion. Working paper, UCLA.

Granger, C. Morgenstein, O. (1970) *Predictability of stock market prices*, Lexington, MA, Heath-Lexington Books,.

Hon, Stauss And Yong. (2004) “Contagion in financial markets after September 11 – Myth or reality?” *Journal of Financial Research* **27**, 95-114.

Huyghebaert, N. Wang, L. (2010) “The comovement of stock markets in East Asia. Did the 1997-1998 Asian financial crisis really strengthen stock market integration?” *China Economic Review* **21**, 98-112.

Johansen, S. (1988) “Statistical analysis of cointegration vectors” *Journal of Economic Dynamics and Control* **12**, 231–254.

Khalid, A.M.; Rajaguru, G. (2007) “Financial market contagion: evidence from Asian crisis using multivariate GARCH approach” Bond University working paper..

Kyle, A.S. (1985) “Continuous auction and insider trading” *Econometrica* **53**, 1315-1335.

Lahrech, A., Sylwester, K. (2008) “US and Latin American stock market linkage” Discussion Papers, Southern Illinois University Carbondale.

Milliaris, A.G. and Urrutia, J. (1992) “The international crash of October 1987: causality test” *Journal of Financial and Quantitative Analysis* **27**, 353-364.

Naoui, K., Liouane, N., Brahim, S. (2010) “A dynamic correlation analysis of financial contagion: the case of the subprime crisis” *International Journal of Economics and Finance* **2**(3), 85-96.

Pagan, J.A. and Soydemir, G. (2000) “On the Linkages between equity markets in Latin America” *Applied Economics Letters* **7**, 207-210.

Tabak, B.; Lima, E. (2002) “Causality and cointegration in stock markets: the case of Latin America” Working Paper Series 56, Banco Central do Brasil.
Wang, P. (2009) *Financial econometrics*. Routledge: New York.
World Bank http://data.worldbank.org/indicator/CM.MKT.LCAP.CD
Yiu, M., Ho, W-Y., and Jin, L. (2010) “Dynamic correlation analysis of financial spillover to Asian and Latin American markets in global financial turmoil” Hong Kong Monetary Authority, Working Paper 01/2010.