Estocástica:
FINANZAS Y RIESGO

# Global Financial Crisis Volatility Impact and Contagion Effect on NAFTA Equity Markets

## Impacto de la volatilidad y efecto de contagio de la crisis global financiera en los mercados bursátiles del TLCAN

Miriam Sosa*

Edgar Ortiz**

Fecha de recepción: 3 de agosto de 2016, Fecha de aceptación 16 de diciembre de 2016

### Abstract

*The aim of this paper is to analyze the contagion effect and the impact of the global financial crisis in NAFTA bloc stock markets´ volatility, using rolling window correlation and a GARCH approach. Once the contagion effect is established through an increasing correlation during the crisis period, volatility changes and leverage effects are tested with symmetric and asymmetric GARCH models with a dummy variable in the variance equation. Canada, the United States and Mexico´s equity markets stock indexes daily yields, in US dollars, from January 2003 through February 2015 were studied. Results confirmed the presence of asymmetric volatility during the whole period and an increasing volatility since the Global Financial Crisis.*

*JEL Classification: G01, G15, F65, C58*

***Key words**: NAFTA, GARCH, TARCH, financial crisis, leverage effect.*

### Resumen

El objetivo de esta investigación es analizar el impacto de la crisis financiera global en la dinámica de la volatilidad de los mercados accionarios del bloque TLCAN, usando correlación medida a través de ventanas móviles y modelos GARCH simétricos (GARCH 1,1) y asimétricos (TARCH 1,1). Las variables financieras empleadas son los rendimientos de los precios de cierre diarios de los índices bursátiles: S&P 500 (Estados Unidos), IPC (México) y S&P TSE Composite (Canadá) en dólares de Estados Unidos, durante el periodo del primero de enero de 2003 al 27 de febrero

* Facultad de Economía, Universidad Nacional Autónoma de México, Ciudad de México, México, msosac87@hotmail.com.

** Programa de Posgrado en Ciencias Políticas y Sociales, Universidad Nacional Autónoma de México, Ciudad de México, México, edgaro@unam.mx.

de 2015. La evidencia confirma la existencia de volatilidad asimétrica en las series durante todo el periodo de estudio, así como incremento en la volatilidad a partir de la crisis bursátil presentada en 2007.

Clasificación JEL: G01, G15, F65, C58

**Palabras clave:** volatilidad asimétrica, GARCH, TARCH, TLCAN, crisis financiera.

## Introduction

The global financial crisis (GFC) has been one of the most significant global events in history concerning economics and finance, due to the fast transmission of its profound impact around the world. The financial crisis first signs began to be evident through the subprime crisis in 2007 and lasted until the end of 2012. Second-round effects appeared until 2015, with the European sovereign debt crisis (Aizenman *et al*., 2012 and Zestos, 2015). These disequilibria were evident by equity markets unsteadiness around the world, characterized by higher stock shares and stock price indexes volatility and lower, and even negative, yields.

The North America Free Trade Agreement (NAFTA), integrated by Mexico, Canada and the United States, (U.S.), relates to one of the geographical zones undergoing important changes due to the GFC. The primary role played by the U.S. in the crisis and its strong relations with Mexico and Canada based on trade, foreign direct investment and, above all, foreign portfolio investments may explain the implications of the global financial crisis in the region.

To a large extent, profound and persistent global financial imbalances were caused by integration. In particular, countries with higher level of integration, as those belonging to the NAFTA bloc, have higher risk exposure to global turmoil. Therefore, to analyze the relation among the NAFTA stock markets is a key factor in order to establish the contagion effect by examining increasing correlation during the crisis. Once crisis transmission effects are determined, the presence of higher volatility and higher leverage effect, since the GFC, can be tested for by modeling NAFTA stock market's volatility through a GARCH approach.

It is of uttermost importance to study equity markets volatility and their relationships in an interconnected and deeply integrated financial backdrop, as is the NAFTA bloc case, since these markets have experienced an accelerated growth. Their rapid rise and development has allowed these stock markets to operate as a link between different economic and social agents (savers, pension funds, public and private investors and issuers), becoming an important investment channel. In this sense, an efficient performance of stock markets, as an investment channel, may enhance economic activity and reinforce economic growth and competitiveness of the NAFTA bloc economies.

On the other hand, this paper shows important implications for asset allocation, for portfolio diversification and, above all, for the construction of trilateral portfolios considering that higher correlation levels and similar responses to external financial shocks inhibit the traditional portfolio diversification techniques. Finally, to examine the volatility behavior of the NAFTA stock markets should shed some light about the integration process between these markets.[1]

This paper is organized as follows. Section 1 presents a review of the literature. Section 2 unfolds the data and methodology used to estimate the contagion effect and the crisis effects stock market volatility. The following section discusses the empirical evidence. Finally, conclusions are presented.

## 1. Evidence from previous studies

Financial integration has increased investment options promoting higher levels of financial assets demand. However, it has also led to the instantaneous transmission of financial disequilibria among markets that, apparently, are not closely related. The growth of interconnections among stock markets and their relations with different economic agents have boosted the external shocks impact on economic activity, leading to the enormous devastation resulting from the recent global financial crisis and its effects. Given the importance of this phenomenon, extensive literature

---

1 If the price of a security, commodity or asset is different in two different markets, then an arbitrageur will purchase the asset in the cheaper market and sell it the most expensive. Otherwise, the markets are integrated.

has been recently published about transmission effects and their impacts on the behavior of equity markets.

NAFTA is one of the world's largest free trade zones. Recently the number and depth of studies dealing with NAFTA´s stock markets has increased. Among these publications stands out the article written by Reyes and Ortiz (2013); they analyze regional diversification through the M-VARCH methodology, which presupposes greater conservatism and precision on estimating potential losses of investment portfolios. Their results show that, despite the interrelation among NAFTA stock markets, there still are opportunities to construct profitable tri-national portfolios.

Among the studies about contagion effect, Chittedi (2015) analyzes the GFC contagion from the US to India. Empirical findings show that there has been a significant increase in the correlation coefficient mean between those markets during the crisis periods compared to the pre-crisis period, which establishes the existence of contagion between the U.S., and Indian markets. Jin & An (2016), analyze the GFC contagion effects between the BRICS´s and the U. S. stock markets. Their empirical results show that there are significant contagion effects from the U. S. to the BRICS´s equity markets. Other recent studies include those by Jawadi *et al*.; Louhichi and Cheffou (2015); Martin and Nguyen (2015); Pragidis *et al*. (2015); and Mollah *et al*. (2016).

Related to the GFC impact on volatility performance, Kalsie and Arora (2016) examine the volatility of the BRICS´s and the U.S. markets. They present evidence about a uniform increase in the absolute volatility during the crisis period compared to the pre-crisis period for all the countries under study. Miniaoui *et al*. (2015) study the performance of Islamic and conventional indexes of the Gulf Cooperation Council (GCC) countries in the wake of the GFC. Their results show that the GFC had an impact on the mean returns of Bahrain, leaving the other indexes unaffected. Recent literature has been also presented by: Kulshreshtha and Mittal (2015); Sinha (2015); Mohammadi and Tan (2015); Syriopoulos, *et al*. (2015); Andriosopoulos *et al*. (2016); Paul and Kimata (2016).

In this paper, two studies were regarded as a starting point. First, the one presented by Mohammadi and Tan (2015) was considered. They used a complementary methodology that integrates correlation analysis and a GARCH approach, in order to analyze contagion and its effects on the U.S., Hong Kong and China stock markets. Secondly, the study developed by Joshi (2012) was reviewed. He applies symmetric and asymmetric GARCH models with a dummy variable in the variance equation to test the presence of increasing volatility and leverage effect since the GFC on the stock markets of India, Korea, Malaysia, Hong Kong and Indonesia.

## 2. Data and methodology

### 2.1 Data

The Daily closing price of Mexico (IPC), Canada (TSE) and the U.S. (S&P500) stock indexes, in US dollars, were used to test contagion effect and changes in the volatility behavior. The time period analyzed includes from January 1, 2003 to February 27, 2015. The pre-crisis period considered comprises January 2003 to August 8, 2007 and the crisis period August 9, 2007 to February 2015, according to the periods identified by Taylor and Williams (2009) and Joshi (2012).

### 2.2 Methodology

The analysis of empirical contagion aims to determine whether or not channels and intensities of shock propagation across countries change during certain crises periods. Particularly, the contagion effect is a phenomenon characterized by a significant increase in correlation levels among different markets as a consequence of a relevant shock from other markets (Sander & Kleimeier, 2003). Considering this definition as a starting point, this study applies a rolling window correlation methodology to test changes in the systemic variation of one variable in relation to another. The correlation index estimation is measured for 60 days rolling window correlation. The estimation changes every day, in order to observe daily changes in the co-movements between two variables.

Figure 1 exemplifies how correlation is estimated every 60 days, from data 1 to data 61, from data 2 to data 62, and so on. In this sense, the rolling window correlation allows to estimate 2395 daily coefficients for each time varying correlation bilateral relation, as shown in the graphic representation for the period under analyses. Significant increasing correlation provides evidence about contagion effect in NAFTA countries stock markets.

Rolling window correlation shows contagion effects, but it does not give information about the crisis effects on volatility behavior. To overcome this limitation, this paper proposes a complementary methodology that includes

Figure 1. Methodology to measure the rolling window correlation graphic representation.


Source: Prepared by author

a GARCH approach, using symmetric and asymmetric models with a dummy variable in the variance equation, proving whether or not the volatility and leverage effect increased since the GFC.

## 2.3 GARCH model

ARCH (Autoregressive Conditional Heteroscedasticity), GARCH models and all their extensions have been identified in the empirical literature as effective in modeling the volatility of financial series. This is because the GARCH models capture some features of the assets returns volatility flows. Among the stylized factors they capture are: thick tails, volatility clustering, leverage effects, cumulative information in non-trading periods, strong inverse relation between volatility and serial correlation and co-movements in volatilities (Bollerslev *et al*., 1994).

Based on the effectiveness and good fit of the GARCH approach on modeling asset prices volatility, this paper used these models in order to prove that the GFC impacted the dynamic of the NAFTA countries stock markets, by increasing their volatility and their volatility asymmetry.

Another advantage of the GARCH models is their parsimony. This allows estimating and interpreting the results in a simple way.

Daily returns are identified as the closing index value natural logarithm difference for two consecutive trading days;

$$R_t = \log(IPC)(t) - \log(IPC)(t-1) \quad (1)$$

Unit root tests were applied to determine that an individual financial series is stationary. Therefore, Augmented Dickey Fuller and Phillips Perron Tests were used . The null hypothesis is $H_0: \delta = 0$ y $H_1: \delta < 1$. The null hypothesis acceptance means that the series has a unit root. Non-stationary series can be transformed through the differentiation of themselves, ARMA, ARIMA and ARFIMA models are commonly used in this process.

GARCH modeling (Bollerslev, 1986 & Taylor, 1986) assumes conditional heteroscedasticity with homoscedastic unconditional error variance. Variance is a function of the realizations of previous error terms and the squared of previous disturbances (Casas & Cepeda, 2008). Thus, the conditional variance of GARCH (p, q) is specified as follows:

$$h_t = \alpha_0 + \sum_{j=1}^{q} \alpha_j \varepsilon_{t-j}{}^2 + \sum_{i=1}^{p} \beta_i h_{t-i} \quad (2)$$

With $\alpha_0 > 0, \alpha_1, \alpha_2, \dots \alpha_q \geq 0$ and $\beta_1, \beta_2, \beta_3, \dots \beta_q \geq 0$ to ensure that the conditional variance is positive, $h_t$ represents the conditional variance estimated considering relevant past information; $\beta_i$ are the lagged GARCH coefficients, which indicate that changes in the conditional variance disappear slowly, in other words, they show volatility persistence; $\alpha_j$ is the error coefficient, if it takes a high value, it means that there is a high sensibility to volatility derived from market movements. If $(\alpha + \beta)$ value is near but lower than the unit, it means that a shock in time $t$ will persist in future periods; a value near one, implies that the series has long memory (Joshi, 2012). This GARCH model is also known as a symmetric model, since it considers that negative and positive variations have the same impact in volatility.

Increasing volatility as a result of contagion effect is determined by introducing a dummy variable in the variance equation as follows:

$$h_t = \alpha_0 + \sum_{j=1}^{q} \alpha_j \varepsilon_{t-j}{}^2 + \sum_{i=1}^{p} \beta_i h_{t-i} + \delta_k D \quad (3)$$

D represents the dummy variable which takes value 0 before August 8, 2007 and one afterwards. If the dummy variable coefficient is positive and statistically significant, an increased volatility was caused by the GFC. Then, the model was tested for ARCH effect using an ARCH-LM test. If the coefficient is not statistically significant, the model will be adequate.

## 2.4 TARCH model

There is a wide range of asymmetric GARCH models: EGARCH de Nelson (1991), GJR-GARCH (Glosten *et al*., 1993), T-GARCH (Zakoian, 1994), APARCH (Ding *et al*., 1993), PNP- GARCH (Bae y Karolyi, *op cit*.) or T- GARCH (Hsin, 2004) are some of them.

The TARCH models proposed in this paper have the following generalized specification of the variance equation:

$$\sigma^2 = \alpha + \sum_{j=1}^{q} \beta_j \sigma_{t-j}{}^2 + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}{}^2 + \sum_{h=1}^{r} \gamma_h \varepsilon_{t-h}{}^2 \, d_{t-h} \qquad (4)$$

if $d_t = 1$ if $\varepsilon_t < 0$

In this model if $\varepsilon_{t-i} > 0$ the possitive residual values are interpreted as positive shocks. If $\varepsilon_{t-i} < 0$, negative residual values represent negative shocks. Positive news has an $\alpha_1$ impact and negative news has a $\alpha_1 + \gamma_1$ effect. Whether $\gamma_1 > 0$, negative news increases volatility, this effect is known as asymetric volatility or leverage effect, in other words if $\gamma_1 \neq 0$ the impact of good and bad news is asymmetric (Joshi, 2012). The main objetive of this paper is to prove asimmetries in terms of possitive and negative shocks.

$$\sigma^2 = \alpha + \sum_{j=1}^{q} \beta_j \sigma_{t-j}{}^2 + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}{}^2 + \qquad (5)$$

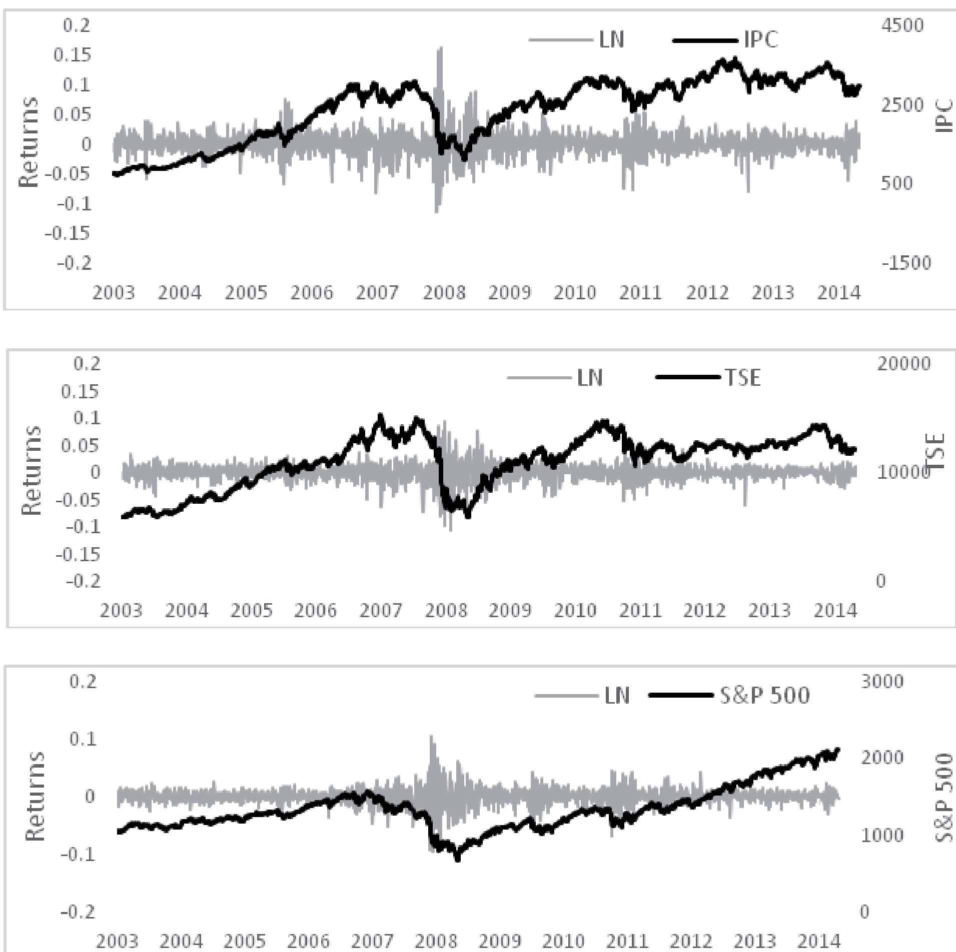
$$\sum_{h=1}^{r} \gamma_h \varepsilon_{t-h}{}^2 \, d_{t-h} + \delta_k Du$$

Here *Du* takes a value of 0 before August 9, 2007 and one afterwards. If the dummy variable coefficient, *Du* is possitive and statistically significant, it indicates an increase in magnitud of leverage effect.

## 3. Empirical analysis

Figure 2 presents the Canada, the U.S. and Mexico level index values and stock index returns, before and during the financial crisis. The increase in all level index values, during the third quarter of 2007, is explained by a speculative bubble peak. This peak was followed by a big fall in all the stock markets resulting from the GFC effects. On the other hand, returns, apparently, present higher changes (increasing volatility) and volatility clusters during the crisis period compared to the pre-crisis period. Overall, all series kept a strong relationship due to general instability and falls in all

Figure 2. Mexico, Canada and the U. S. Level Value and Stock Price Index Returns (January, 2003-February, 2015)




Source: Prepared by author using Bloomberg and Economatica data.

the stock markets. These facts are analyzed through the implementation of the methodology in the following section.

Table 1 shows the date of the maximum positive and negative variations and the highest and lowest levels for each index. Maximum variations (positive and negative) occurred when the crisis turned into a global financial crisis, after the failure of Lehman Brothers in september 2008. The lack of coincidence between the date of the highest and the lowest level suggests that these facts may be related to local conditions.

*Table 1. Stock Price Index Maximum Positive and Negative Variation and Highest and Lowest level index values*

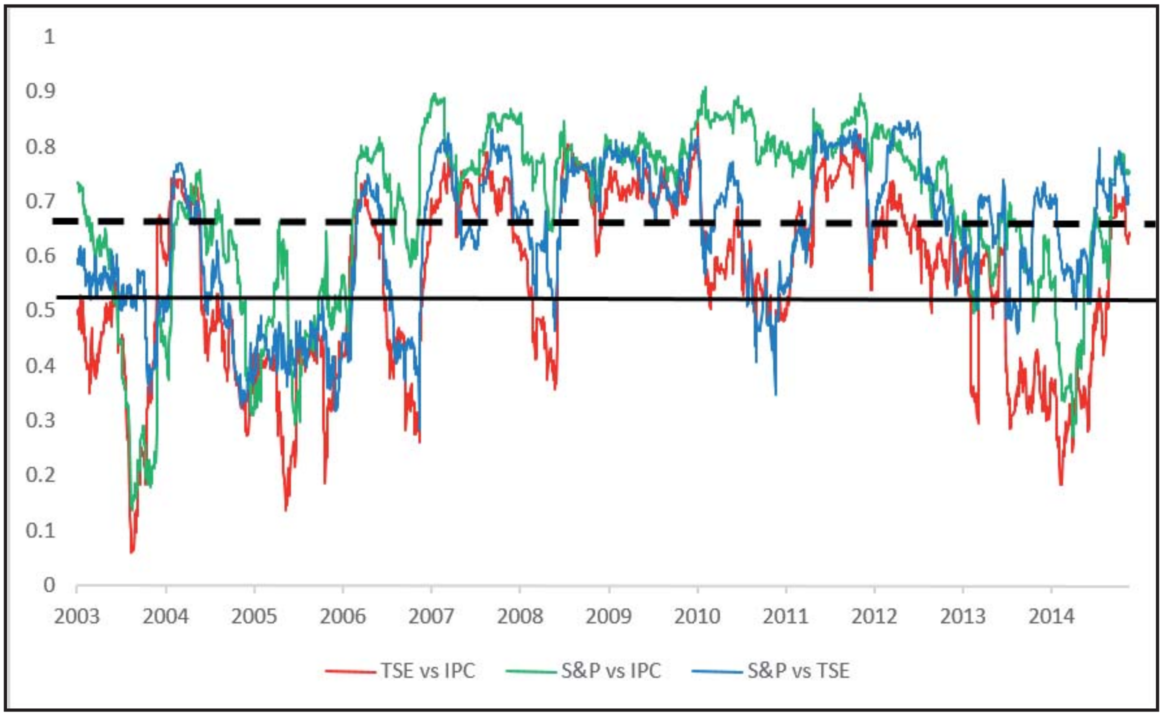
| Index | | Level | | Maximum variation | |
|---|---|---|---|---|---|
| | | High | Low | Positive | Negative |
| IPC | Level/Change | 3680.127 | 722.170 | 0.162 | -0.115 |
| | Date | 11/04/2013 | 24/11/2003 | 29/10/2008 | 06/10/2008 |
| TSE | Level/Change | 15323.764 | 5849.301 | 0.095 | -0.105 |
| | Date | 31/10/2007 | 18/05/2004 | 29/10/2008 | 01/12/2008 |
| S&P 500 | Level/Change | 2115.480 | 676.530 | 0.104 | -0.095 |
| | Date | 24/02/2015 | 09/03/2009 | 14/10/2008 | 15/10/2008 |

Source: Prepared by author using Bloomberg and Economatica data.

## 3.1 Rolling window correlation analysis

Figure 3 shows changes in the correlation index among NAFTA countries equity markets. The Mexican and the U.S. stock markets held the highest correlation levels during the whole period. The second most important relationship is between the Canadian and the U.S. markets. The lowest correlations levels were those presented by the Mexican and the Canadian equity markets. This last result may be caused by the geographical location of both the Mexican and Canadian markets next to the U.S. economy and not by a close relationship between them, as well as, by the fact that the U.S. is the largest portfolio foreign investment source and recipient country.

Figure 3. Rolling window correlation results




Source: Prepared by author based on results obtained.

Two lines can be observed in Figure 3, the first one, from the bottom up, corresponds to the correlation coefficient average before the crisis, which is 0.53; while the discontinuous line above it represents the correlation coefficient after the crisis, which has a value of 0.68. It is important to mention that, the correlation average, as an immediate effect of the crisis (August 2007-December 2012) is above 0.7. In this sense, related literature has identified that a correlation level higher than 0.7 represents strong correlation. Hence, Figure 3 provides evidence about contagion effect on NAFTA stock markets during the GFC.

## 3.2 GARCH model results

Descriptive statistics of NAFTA countries equity markets indexes are presented in Tables 2 and 3. Standard deviation, mean, kurtosis, skewness, Jarque Bera and ARCH-LM tests are included. Table 2 contains the pre-crisis period results and table 3 shows the descriptive statistics outcome of the crisis period in order to compare the financial series performance between two periods.

Table 2. Descriptive Statistics before Crisis Period- January 1, 2001 to August 8, 2007

| Country | S. D. | Mean | Kurtosis | Skewness | Jarque Bera | ARCH F-statistics | ARCH Probability |
|---|---|---|---|---|---|---|---|
| **US** | 0.0084 | 0.0005 | 4.3735 | -0.0342 | 73.99635* | 5.81 (2)* | 0.00 |
| **Canadá** | 0.0098 | 0.0012 | 4.2862 | -0.3532 | 84.2478* | 3.48 (3)** | 0.02 |
| **México** | 0.0145 | 0.0016 | 5.9237 | -0.2688 | 345.745* | 9.78 (1)* | 0.00 |

Reported values are statistically representative at *1%,** 5% and ***10% significance levels.

Note: the statistic test ARCH LM corresponds to the Lagrange multiplier used to detect the ARCH effect; the null hypothesis represents the absence of heteroscedasticity, distribution of that parameter is $\lambda^2(k)$.

Table 3. Descriptive Statistics Crisis Period- August 8, 2007 to February 27, 2015

| Country | S. D. | Mean | Kurtosis | Skewness | Jarque Bera | ARCH (1) F-statistics | ARCH (1) Probability |
|---|---|---|---|---|---|---|---|
| **US** | 0.015 | 0.0002380 | 10.371 | -0.454 | 3483.70* | 172.03* | 0.00 |
| **Canada** | 0.016 | -0.0000319 | 9.703 | -0.484 | 2897.44* | 191.95* | 0.00 |
| **Mexico** | 0.020 | 0.0000574 | 11.086 | 0.256 | 4146.74* | 103.35* | 0.00 |

Reported values are statistically representative at * 1%,** 5% and ***10% significance levels.

Note: As in Table 2, the statistic test ARCH LM corresponds to the Lagrange multiplier used to detect the ARCH effect; the null hypothesis represents the absence of heteroscedasticity, distribution of that parameter is $\lambda^2(k)$.

It can be observed that volatility, measured by the increase in the standard deviation, is much higher after the crisis for all the markets. The returns distribution is negatively skewed during the pre-crisis period in all cases and negatively biased in the crisis period, except for the Mexican market that is positively biased, indicating the presence of asymmetry. The values concerning kurtosis suggest that, the distribution is leptokurtic with a high concentration on the central values and the presence of heavy tails. Additionally, LM ARCH results indicate the presence of ARCH effect for each and every one of the series under study. Since the GARCH model is suitable for modeling leptokurtic series, it is expected to correctly analyze equity markets indexes behavior. Finally, values of the ARCH (1,1) shown in Tables 2 and 3 imply the presence of clusters of volatility, where large changes in volatility tend to be followed by large changes and small changes tend to be followed by small changes (Engle and Bollerslev, 1986). Consequently, the probabilities of Jarque-Bera testing reported in Tables 2 and 3, allow the rejection of the normal distribution hypothesis at the 1% significance level.

The condition of stationarity was tested applying the Phillips Perron and the Augmented Dickey Fuller tests. Results reported in Table 4 suggest

Table 4. Unit Root Testing of Daily Returns of Stock markets

| | ADF | | | | Phillips- Perron | | | |
|---|---|---|---|---|---|---|---|---|
| | Pre-crisis | | Crisis | | Pre-crisis | | Crisis | |
| | Levels | FD | Levels | FD | Levels | FD | Levels | FD |
| **U. S.** | -32.46 | -16.59 | -43.26 | -21.41 | -32.72 | -307.81 | -43.26 | -376.45 |
| | (0.00)* | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| **Canada** | -29.98 | -14.69 | -35.25 | -17.16 | -29.99 | -322.64 | -35.21 | -369.68 |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| **Mexico** | -29.48 | -18.26 | -35.19 | -18.75 | -29.34 | -313.92 | -38.02 | -332.14 |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |

Critical MacKinnon criteria at a significance level of 1% is -3.44. Null hypothesis, series has unit root

*Values within parentheses indicate probabilities that the null hypothesis about the presence of a unit root is rejected; values of stock indexes are greater than the critical MacKinnon value at a 1% significance level. Therefore, it is confirmed that the series are stationary both for levels (logs) and for the first differences.

To confirm that the series are stationary, a regression equation for the average yield for each of the stock exchanges is performed by applying the Breusch-Godfrey test. The null hypothesis requires that the residuals are not serially correlated. The evidencia suggests that the probability value is greater than 0.05, rejecting the existence of autocorrelation.

## 3.3 Application of the GARCH (1,1) model

For parameter estimation the Marquardt optimization logarithm was employed, in conjunction with the maximum likelihood method. Derived from maximum likelihood analysis a GARCH (1,1) model was chosen, since the other models presented negative coefficients $\alpha_1$ y $\beta_1$ for all $i \neq 0$, or they were not significant at least at a 90% confidence level.

Results of the GARCH (1,1) dummy variable for the TLCAN financial series, are reported in Table 5. The GARCH model is tested using the ARCH-LM statistic, revealing the presence of an ARCH effect after applying the models, results from this test are statistically significant, their probability is higher than 0.05.

Furthermore, Table 5 shows that all parameters estimated by the GARCH (1,1) model are positive and statistically significant, with a probability of less than 0.05. In addition, the value of the parameter estimate is higher in all cases than the value of $\alpha_1$, as well as, the sum $\alpha_1+\beta_1$ is smaller and very close to one, such condition insures that the ARCH process is stationary, i.e. the variance does not increase indefinitely. The fact that the lag coefficient of the conditional variance was larger than the error coefficient $\alpha_1$ implies that there is a persistence of shocks with effects in the long run, that is, volatility does not decay rapidly but tends to remain and its effect dies off gradually.

The coefficients of the dummy variables introduced in the variance equation (GARCH dummy) are positive, except for the case of Canada; they are also statistically insignificant in the case of Mexico and Canada and in the U. S. case the coefficient is statistically significant at 10% significance level; this suggests that volatility increased in the U. S. market after the crisis. However, these results indicate the need to apply a TARCH model to examine the presence of asymmetric volatility and an increase in volatility following

Table 5. GARCH models coefficients -January 1, 2001 to February 27, 2015

| Coefficients | Mexico | U. S. | Canada |
|---|---|---|---|
| **α0** | 7.47E-06 | 2.52E-06 | 1.93E-06 |
| | (0.00)* | (0.00) | (0.00) |
| **α1** | 0.0946 | 0.1027 | 0.0668 |
| | (0.00) | (0.00) | (0.00) |
| **β1** | 0.8782 | 0.8746 | 0.9236 |
| | (0.00) | (0.00) | (0.00) |
| **α1+β1** | 0.9728 | 0.9701 | 0.9905 |
| **GARCH** | | | |
| **Dummy** | 1.24E-06 | 7.20E-07 | -3.17E-07 |
| 0.2198 | 0.0732 | 0.3007 | |
| **ARCH LM** | 0.0077 | 3.3911 | 0.1118 |
| | (0.9297) | (0.0657) | (0.7381) |

*Values within parentheses indicate probabilities.

the financial crisis. The GARCH model is tested for its fitness and adequacy using ARCH-LM test. Results indicate that there was no ARCH effect after applying the GARCH models, since ARCH LM tests are not statistically significant as their probability value is higher than 0.05.

## 3.4 Crisis and volatility changes applying a TARCH model

The financial literature, provides ample evidence proving that changes in the conditional volatility of stock returns not only depends on the magnitude of the shocks, but also on its signs; namely, good and bad news leads to different results. Bad news yields greater changes in volatility than good news which can be tested applying a TARCH (1, 1) model with a dummy variable in the variance equation. Results of its implementation are shown in Table 6.

In Table 6, the leverage term (γ) represented by RESID < 0 ARCH (1) is greater than zero and statistically significant, reinforcing the assumption that positive and negativa shocks have different effects on the volatility of daily stock returns. Good news has an impact of $\alpha_1$, while bad news´ impact is $\alpha_1 + \gamma$, therefore, the impact of bad news is larger than that of good news in all financial markets analyzed. In this regard, the Canadian market shows a more pronounced effect on the asymmetry of volatility, followed by the Mexican and the U.S. markets. Therefore, the evidence confirms that negative impacts produced a leverage effect.

Results reported for the dummy variable indicate that the financial crisis did not increase the magnitude of the leverage effect on the NAFTA financial markets, where the probability associated with the dummy variable is not statistically significant and, in the case of Mexico and Canada, the dummy coefficient is negative. Meanwhile, the values of the one lag ARCH- LM values are statistically insignificant, with a probability value higher than 0.05.

Table 6. TARCH models coefficients -January 1, 2001 to February 27, 2015

| Coefficients | Mexico | U. S. | Canada |
|---|---|---|---|
| **α0** | 6.70E-06 | 1.17E-05 | 2.29E-06 |
| | (0.00)* | (0.00) | (0.00) |
| **α1** | 0.003568 | 0.17777 | 0.035707 |
| | 0.5261 | (0.00) | (0.00) |
| **β1** | 0.130937 | 0.199725 | 0.052788 |
| | (0.00) | (0.00) | (0.00) |
| **RESID<0 ARCH (1) γ** | 0.90793 | 0.703279 | 0.924504 |
| | (0.00) | (0.00) | (0.00) |
| **α1+ γ** | 0.911498 | 0.881049 | 0.960211 |
| **Dummy in variance** | -1.09E-06 | 5.01E-07 | -6.24E-07 |
| | (0.1346) | (0.7707) | (0.0381) |
| **ARCH LM** | 0.4542 | 0.7475 | 0.2126 |
| | (0.5004) | (0.4548) | (0.6447) |

*Values within parentheses indicate probabilities.

As previously mentioned, the Canadian market presented higher volatility and leverage effect, followed by the Mexican market. It could be because of the size of the Canadian market and its recent merger process that started in 2011 and officially finished in 2014. This merger process has given place to the second higher transatlantic market, combining the London Stock Exchange Group plc (LSEG) with the TMX Group. These types of international operations could increase the global risk exposure.

## 4. Conclusion

This paper analyzes the contagion effect and volatility changes of the stock market indexes for the countries comprising the NAFTA bloc: Mexico, Canada and the U. S. Its aim was to unveil whether or not those markets were characterized by asymmetric volatility as well as if such effect became accentuated due to the global financial crisis, which began in 2007 with disequilibria in the U. S. market. Data examined included January 1, 2003 to February 27, 2015. The methodology employed to prove the contagion effect was rolling window correlation, and to capture the dynamics of the volatility returns of the IPC, TSE and S&P500 indexes, GARCH (1,1) and TARCH (1,1) models were used.

The rolling window correlation analysis offers evidence about contagion effect among the NAFTA countries stock markets. The equity indexes more closely related are IPC and S&P followed by TSE and S&P. This evidence has important implications on asset allocation and risk diversification concerning tri-national portfolios among these equity markets. Portfolio weights should be carefully optimized to benefit from higher risk returns from the Mexican market and lower risk-return performance from the other two bloc members, particularly the low correlation between the Canadian and Mexican stock markets.

Empirically, the stationarity of the series, the presence of ARCH effect and normality were first verified. Then, relevant models were chosen applying maximum likelihood analysis identifying a GARCH (1, 1) model as the most suitable. The empirical evidence suggests the persistence of shocks with long run effects. Results associated with the dummy variable indicated that volatility in the Mexican and Canadian markets were not very large following the crisis, nevertheless in the case of the U. S., equity markets indexes increasing volatility since the global financial crisis, was confirmed.

Finally, a TARCH (1, 1) model was applied to determine the presence of asymmetric volatility impacts on the returns of the NAFTA markets and, likewise, if such asymmetry increased following the financial crisis. Findings show that for the three stock exchanges there was a leverage effect in their return series; that is, negative news have a larger impact than positive ones on volatility. The Canadian market shows the largest asymmetry in volatility, followed by the stock markets from Mexico and the U. S., respectively. With regard to the effects of the financial crisis on volatility behavior, results about the dummy variable indicate that the financial crisis did not accentuate the asymmetrical behavior of volatility. These latter results may be indicative of a greater integration among the Mexican, Canadian and the U.S. markets due to their similar reaction to exogenous shocks.

The importance of this type of analysis consists in emphasizing that long memory and leverage effect inhibit investment operations, and higher market yields imply higher costs for corporations issuing shares and bonds, which affect the real economy, generates more expensive funding, increases prices and discourages investment. As a corollary, for policy makers, findings imply the need to enhance their stock markets to further economic integration and development.

## Referencias bibliográficas

Aizenman, J., Jinjarak, Y., Lee, M., & Park, D. (2012). "Developing Countries' Financial Vulnerability to the Euro Crisis: An Event Study of Equity and Bond Markets (No. w18028). *National Bureau of Economic Research*.

Andriosopoulos, K. D., Galariotis, E. C., & Spyrou, S. I. (2016). "Contagion, Volatility Persistence, and Volatility Spill-Overs: The Case of Energy Markets During the European Financial Crisis." *Available at SSRN 2718841*.

Bae K. H. and G. A. Karolyi (1994). "Good News, Bad News and International Spillovers of Stock Return Volatility Between Japan and the US". *Pacific-Basin Finance Journal*, 2, pp. 405-438.

Bollerslev, T. (1986). "Generalized Autoregressive Conditional Heteroskedasticity"*. Journal of Econometrics* 31, pp. 307-327.

Bollerslev, T., Engle, R. F., & Nelson, D. B. (1994). "ARCH models". *Handbook of econometrics*, 4, pp. 2959-3038.

Casas, M. and Cepeda, E. (2008). "Modelos Arch, Garch y EGarch: Aplicaciones a Series Financieras". *Cuadernos de Economía,* vol. XXVII, núm. 48, Bogotá 2008, pp. 287-319.

Chittedi, K. R. (2015). "Financial Crisis and Contagion Effects to Indian Stock Market: 'DCC–GARCH'Analysis". *Global Business Review*, 16(1), pp. 50-60.

Ding Z., Granger C. W. J. and Engle R. F. (1993). "A Long Memory Property of Stock Market Returns and a New Model". *Journal of Empirical Finance.* 1(1), pp. 83-106.

Engle, R. F., & Bollerslev, T. (1986). "Modelling the Persistence of Conditional Variances". *Econometric reviews*, 5(1), pp. 1-50.

Glosten L. R., R. Jagannathan and D. E. Runkle (1993). "On the Relationship Between the Expected Value and the Volatility of the Nominal Excess Return on Stocks". *The Journal of Finance.* 48(5), pp. 1779-1801

Hsin C. W. (2004). "A Multilateral Approach to Examining the Comovements Among Major World Equity Markets". *International Review of Financial Analysis*, 13(4), pp.433-462.

Jawadi, F., Louhichi, W., & Cheffou, A. I. (2015). "Testing and Modeling Jump Contagion Across International Stock Markets: A Nonparametric Intraday Approach". *Journal of Financial Markets*, 26, pp. 64-84.

Jin, X., & An, X. (2016). "Global Financial Crisis and Emerging Stock Market Contagion: A Volatility Impulse Response Function Approach". *Research in International Business and Finance*, 36, pp. 179-195.

Joshi, P. (2012). "Financial Crisis and Volatility Behaviour of Stock Markets of Asia". *Quest-Journal of Management and Research*, 2(2), pp. 35-44.

Kalsie, A., & Arora, A. (2016). "Analysis of the Impact of US Financial Crisis on BRICS Economies using ANOVA". *FOCUS. Journal of International Business*, 2(2).

Kulshreshtha, P., & Mittal, A. (2015). "Volatility in the Indian Financial Market Before, During and After the Global Financial Crisis". *Journal of Accounting and Finance*, 15(3), p. 141.

Martin, F., & lan Nguyen, M. (2015). "Asymmetric Dynamics in the Correlations of Hedge Fund Strategy Indices: What Lessons About Financial Contagion?" *Economics Bulletin*, 35(4), pp. 2110-2125.

Miniaoui, H., Sayani, H., & Chaibi, A. (2015). "The Impact of Financial Crisis on Islamic and Conventional Indices of the GCC Countries". *Journal of Applied Business Research*, 31(2), p. 357.

Mohammadi, H., & Tan, Y. (2015). "Return and Volatility Spillovers across Equity Markets in Mainland China, Hong Kong and the United States". *Econometrics*, 3(2), pp. 215-232.

Mollah, S., Quoreshi, A. S., & Zafirov, G. (2016). "Equity Market Contagion During Global Financial and Eurozone Crises: Evidence From a Dynamic Correlation Analysis". *Journal of International Financial Markets,* Institutions and Money.

Nelson, D. B. (1991). "Conditional Heteroskedasticity in Asset Returns: A New Approach". *Econometrica: Journal of the Econometric Society*, pp. 347-370.

Paul, M. T., & Kimata, J. D. (2016). "The Linkages, Persistence, Asymmetry in the Volatility, the Price Discovery and Efficiency, and the Effect of the US Subprime Mortgage Financial Crisis on the Spot and the Futures Market's Returns: the Case of India". *Applied Economics*, 48(8), pp. 669-683.

Pragidis, I. C., Aielli, G. P., Chionis, D., & Schizas, P. (2015). "Contagion Effects During Financial Crisis: Evidence From the Greek Sovereign Bonds Market". *Journal of Financial Stability*, 18, pp. 127-138.

Reyes, F. J. Z., & Ortiz, E. (2013). "Modelos VAR-GARCH y portafolios de inversión trinacionales en los mercados accionarios del TLCAN". *Revista Mexicana de Economía y Finanzas. Nueva Época/Mexican Journal of Economics and Finance*, 8(2), pp. 129-155.

Sander, H., & Kleimeier, S. (2003). "Contagion and Causality: an Empirical Investigation of four Asian Crisis Episodes". *Journal of International Financial Markets, Institutions and Money*, 13(2), pp. 171-186.

Sinha, A. (2015). "Nature of Energy Index Volatility in Post Financial Crisis Period: Evidences from India". *Energy Procedia*, 75, pp. 2556-2562.

Syriopoulos, T., Makram, B., & Boubaker, A. (2015). "Stock Market Volatility SpillOvers and Portfolio Hedging: BRICS and the Financial Crisis". *International Review of Financial Analysis*, 39, pp. 7-18.

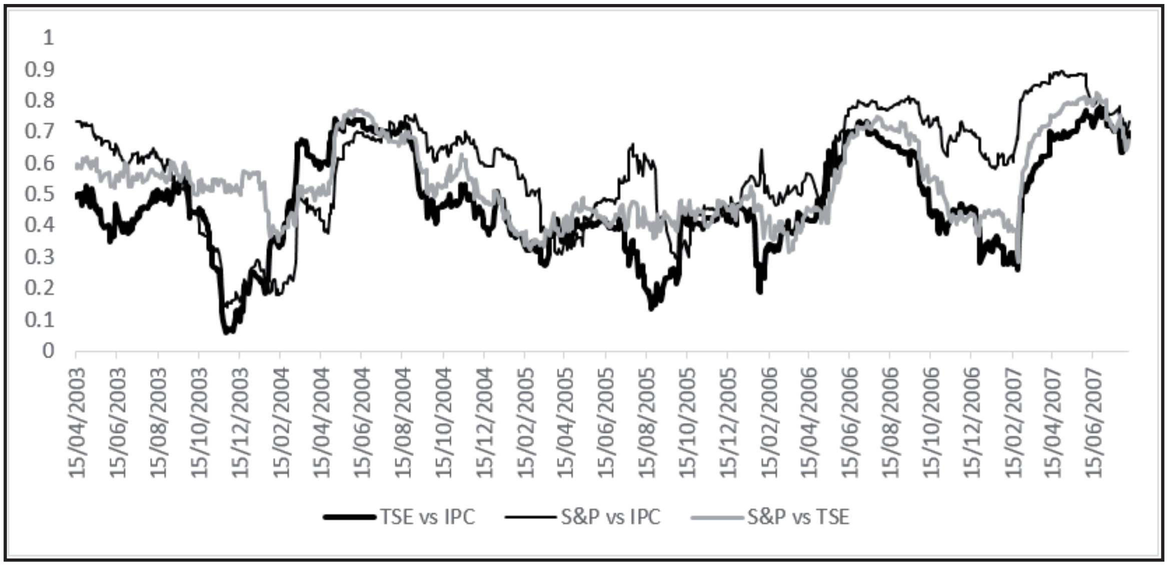
Taylor, S. (1986). *Modeling Financial Time Series*. John Wiley & Sons, New York.

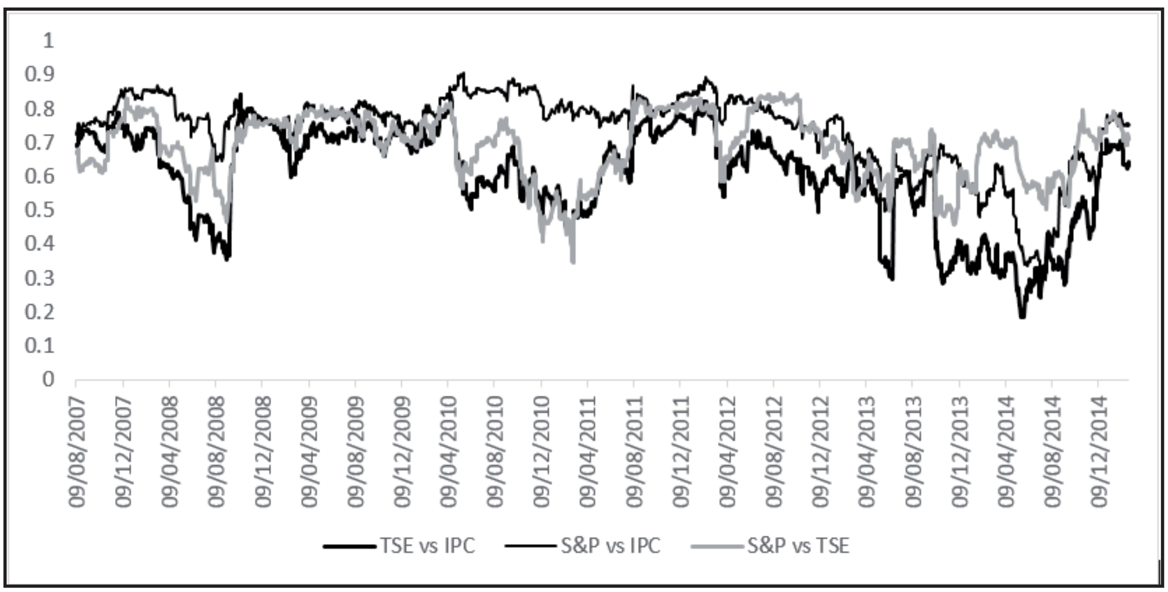
Taylor, J. B., & Williams, J. C. (2009). "A Black Swan in the Money Market". *American Economic Journal: Macroeconomics*, 1(1), pp. 58-83.

Zakoian J. M. (1994). "Threshold Heteroskedastic Models". *Journal of Economic Dynamics and Control*, 15, pp. 931-955.

Zestos, G. K. (2015). *The Global Financial Crisis: From US Subprime Mortgages to European Sovereign Debt*. Routledge.

# APPENDIX 1
## Rolling window correlation, pre-crisis period
## (Jan 1, 2003- Ago 8, 2007)




Rolling window correlation, crisis period (Ago 9, 2007- Feb 27, 2015).