THE CONTAGION EFFECTS OF FINANCIAL CRISIS ON STOCK MARKETS:WHAT CAN WE LEARN FROM A COINTEGRATED VECTOR AUTOREGRESSIVE APPROACH FOR DEVELOPED COUNTRIES?

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Abstract

This research applies a set of diversified tests that have not been used on a joint basis to study the contagion effects of financial crises in the stock markets of developed countries. This is particularly important due to the fact that the existing literature has, so far, failed to adequately address the effects of financial crisis on such markets. Several empirical tests are performed on a joint basis: correlation tests; Kolmogorov-Smirnov tests; extreme value tests; and tests based on the estimation of Cointegrated Vector Autoregressive models. Significant evidence on the existence of contagion effects is provided with regards to the Asia crisis, the Russia crisis and the September 11 crisis. Finally, limited evidence is detected regarding the contagion effects on Brazil, Argentina and Mexico crisis.

Resumen

Esta investigación aplica un conjunto de pruebas diversificadas que no se han utilizado en forma conjunta para estudiar los efectos de contagio de las crisis financieras en los mercados bursátiles de los países desarrollados. Esto es particularmente importante debido al hecho de que en la literatura existente no se abordan adecuadamente los efectos de las crisis financieras en dichos mercados. Se realizan varias pruebas empíricas en forma conjunta: pruebas de correlación; de Kolmogorov-Smirnov; de valor extremo; y las pruebas basadas en la estimación de modelos de vectores autorregresivos cointegrados. Se muestra evidencia significativa de efectos de contagio durante la crisis asiática, la crisis de Rusia y la crisis del 11 de Septiembre. Por último, los efectos de contagio encontrados durante las crisis en Brasil, Argentina y México son limitados.

JEL classification: C30, C32, G10, G15.
Keywords: Cointegration, Contagion, Stock Markets, Developed Countries.

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1. Introduction

Until the 1980s, financial crises were seen as events that happened in individual markets, without a systemic nature. For this reason, at that time, the possibility of effects transmission between countries deserved little attention from researchers. During the 1990s the situation changed, due to the occurrence of several financial crises such as the crisis of the European Mechanism of Exchange Rates (1992), the crisis in Mexico (1994-1995), the crisis in Asia (1997-1998), the Russian crisis (1998) and the Brazilian crisis (1999). One of the most impressive characteristics of these crises was that the moment of their occurrence and their intensity did not seem to be related to the fundamental problems that were faced by those countries. Furthermore, the negative consequences associated with the instability episodes were not limited to the countries of origin, being quickly transmitted all over the world to several international markets. This started to be designated in the literature as the contagion effect.[1]

It is important to study the transmission of shocks among international finance markets for different reasons. Firstly, contagion may have deep implications for portfolio management, particularly in the processes of international diversification of risk. Secondly, the importance of studying the contagion problem has been reinforced by the tendency for integrating financial markets on a worldwide basis. Thirdly, the study of contagion is important to better understand the role and the effectiveness of the interventions of the international financial institutions in contexts of crisis.

There are several explanatory theories of contagion. The theoretical approach to contagion presents two main causes for its occurrence: the fundamental causes and the pure contagion. The fundamental causes may have a commercial or a financial nature. This article presents a significant contribution for two reasons. First, the effects of contagion are analysed in crisis episodes on the financial markets of nine developed countries. This contribution assumes a special importance, since the literature usually focuses on the contagion effects on the financial markets of emergent economies that are located in North America, South America and Asia. Second, a contribution at the level of research methodology is also made, in the sense that an innovative approach is developed through the use of two blocks: the methodology and the empirical analysis. In this sense, a large set of tests is used fundamentally to seek maximum accuracy in the process of detecting the contagion effects that originated from six emblematic episodes of financial crisis.

[1] There is no generally accepted definition of contagion. It is usual to make reference to the three definitions adopted by the Word Bank. The broad definition asserts that contagion is an across-country transmission of shocks or the general cross-country spillover effects. According to the restrictive definition, contagion is the "transmission of shocks to other countries () beyond any fundamental link among the countries and beyond common shocks". The very restrictive definition by the World Bank describes contagion as an increase in the cross-country correlations in crisis times compared to calm times. This last view of contagion is in line with the notion adopted in the article, although we do not limit the study of the impact of contagion to the correlation effects.

This study aims to evaluate the contagion effects between the financial markets of nine developed countries (Portugal, Spain, Ireland, Greece, France, United Kingdom, Germany, USA and Japan), by making use of daily frequency data, during the period 1993-2004 and, in particular, during six selected episodes of financial crisis: the crises in Mexico (1994-1995), Asia (1997-1998), Russia (1998), Brazil (1999), the crisis of the September 11 terrorist attacks (2001) and the Argentinean crisis (2001-2002). Thus, the results are obtained through the application of an innovative research methodology that includes several contagion tests, such as correlation tests; Kolmogorov-Smirnov tests; tests of extreme value and tests based on the estimation of Cointegrated Vector Autoregressive (CVAR) Models.

One of the differentiating contributions of this paper is related to the study of contagion effects on developed countries. This is quite different from the observed tendency in the contagion literature that focuses particularly on the behaviour of financial markets in emerging economies. After identifying this omission in the literature, and taking into consideration the view of Nagayasu (2001), who states that, in the short term, daily data allows the detection of contagion effects that could be not detected in analyses that use less frequent data, we opted for the use of daily data. This allows us to present a different analysis in relation to the generality of contagion studies, which usually make use of weekly or monthly data.

The paper is organized as follows. In the second section, a literature review of existing studies about episodes of financial crisis and contagion effects is made. In the third section the methodology and the database used in the study are presented. In the fourth section the empirical findings are presented, and the main results are discussed using a comparative approach. Lastly, the main conclusions and future research directions are presented.

2. Literature Review: Empirical Evidence

Bourguinat (1992) distinguishes two types of contagion: horizontal and vertical contagion. Horizontal contagion is related to the interconnection of financial markets. The linkage between the prices, which is ensured through the application of automatic rating procedures, of the NASDAQ kind, allows the automatic quotation of thousands of shares in London and in New York. Vertical contagion is explained through the interrelation among the markets. Malliaris and Urrutia (1992) analysed the influence of the 1987 crash on six international stock markets by using the concept of Granger causality (1969, 1988). The results revealed the existence of causality in the month when the crash took place (*i.e.* October), although this kind of evidence was detected neither in the pre-crash period nor in the post-crash period.

Masih and Masih (1997) analysed the relationships among five stock market indices: the DOW JONES, the NIKKEI, the CAC, the DAX, and the FTSE, both in the period before and after the crash of 1987, using a Vector Autoregressive (VAR) model with an error correction mechanism. An analysis of causality relations, Cholesky's variance decomposition, and impulse-response functions were presented. The main results revealed that the crash did not affect the

"leadership" role of the DOW JONES, while the English and the German stock indices became more dependent on other indices in study.

Baig and Goldfajn (1999) analysed several variables, such as the profitability of the share indices, the interest rates, the spreads of debt and the exchange rates of five Asian countries (Indonesia, Korea, Malaysia, the Philippines and Thailand). The objective was to verify the occurrence of excessive co-movements in the reference variables during the Asian crisis. The authors concluded that, for each variable, most of the correlation coefficients among the countries increased significantly in the period of turbulence. These effects were more pronounced in relation to currency values and spreads of the debt than in the profitability of shares. Park and Song (2000) developed a comparative study between the period of crisis of a wide number of Asian countries (in 1997) and the correspondent calm period by making use of the correlation coefficients of the residuals of the autoregressive model. The authors showed that the crisis in Southeast Asia did not directly unleash the crisis in Korea, but its propagation in Taiwan assumed a particular importance in terms of the evolution of the crisis of that country.

Regarding contagion studies based on tests that are performed through the estimation of VAR models, the works of Edwards (2000), Nagayasu (2001) and Bazdresch and Werner (2001) should be emphasised. Edwards (2000) used VAR models and variance decomposition in order to study the relationship between the interest rates of Chile and other emergent markets in the period 1994-1999. The results showed that significant contagion effects have occurred since 1997. Nagayasu (2001) used daily data about exchange markets and shares in Thailand and the Philippines, during 1996 and 1998, in order to analyse the causality relationship between those markets, through the use of unit root tests, cointegration tests, VAR models and Granger causality tests. The author revealed that the movements of prices in some sectors of Thailand's stock markets caused the variations in the Philippine currency in a Grangerian sense. Bazdresch and Werner (2001) made use of VAR models and variance decomposition to explain the transmission of profitability shocks among stock markets, exchange rates and debt, in the case of Mexico, during the crises of Asia, Russia and Brazil. The results showed the presence of contagion during all the crisis episodes, especially in the share markets and debt markets.

The following studies are also important contributions. Gelos and Sahay (2001) studied contagion effects in the economies of Central and Eastern Europe, Russia and the Baltic since 1993. They also used VAR models and Granger causality tests to study share markets, exchange markets, debt markets and interest rates. The authors concluded that, after the Russian crisis of 1998, the movements of the European emergent markets were similar to the movements observed in many Asian and Latin American markets during the Asian crisis. The shocks originating from the Russian shares market caused the movements in the markets of the Czech Republic, Hungary and Poland in a Grangerian sense. The authors rejected the hypothesis that there was contagion originating from the markets of the Czech Republic, Asia and Russia, in the direction of the European financial markets.

Forbes and Rigobon (2002) applied correlation tests to the daily levels of share profitability and to the short term interest rates of 28 developed and emergent economies, during falling periods of US shares *i.e.* October 1987, in the Mexican crisis of 1994 and in the Asian crisis of 1997. The hypothesis of contagion was rejected in most of the markets that were analysed. Sander and Kleimeier (2003) studied the behaviour of the bonds markets in 11 emergent economies during the crises of Asia and Russia. The results ratified the conclusions of Kaminsky and Reinhart (2001) regarding the Asian crisis, and they indicated that the Russian crisis had caused significant changes in the causality patterns among the markets.

Chan-Lau *et al.* (2004) used tests of extreme value to evaluate the evolution of contagion among 16 emergent and developed markets in the period 1988-2001. The authors concluded that the Russian and Brazilian crises had durable effects since they caused the increase in the propensity for new contagion episodes particularly among the developed markets, between the developed markets and the Latin American markets, and also within Latin American markets. Gande and Parsley (2005) studied the interdependence patterns in the daily spreads of the 34 countries' bonds for the period 1991-2000. The authors detected significant contagion effects that were explained by the existence of capital flows among economies. Gande and Parsley (2005) and Dreher *et al.* (2006) make use of Granger causality tests in order to study the interdependence patterns between debt markets and exchange markets.

Dreher *et al.* (2006) used data from 80 non-industrialised countries for the period 1975-2000, whereas Herz and Tong (2005) considered 74 developing countries for the period 1975-2001. In both studies, the results obtained from the application of causality tests allowed the conclusion that crisis episodes in the debt markets preceded the occurrence of crises in the exchange markets. Chiang *et al.* (2007) question the benefits of international portfolio diversification after finding high levels of contagion during the Asian Crisis. A statistical analysis of correlation coefficients is employed to detect shifts in the level as well as in the variance of correlations. Gkelezakou and Mylonakis (2009) applied correlation tests, unit root tests and Granger causality tests to examine the developing stock markets of South Eastern Europe (Romania, Bulgaria, Croatia, Slovenia, Turkey and Greece) before and during the most recent economic crisis, starting in 2007. The results suggest that these markets exhibit stronger interrelationships under conditions of economic recession. Naoui *et al.* (2010) studied the financial contagion that followed the subprime crisis using a correlation-based measure. The authors conclude that the interdependence between the financial markets under analysis - 5 developed stock markets and 10 emerging stock markets - increased significantly in the period of turmoil.

According to the literature review of studies on contagion effects, the limited focus of previous studies should be underlined, since they concentrated on analysing the behaviour of the shares markets of emergent economies. In this sense, the current study aims to overcome the incomplete nature of the previous studies through the development of a complete analysis of contagion effects of six episodes of international financial crises. For this purpose, we present an innovative approach that is structured in two blocks: the methodology and the

empirical analysis. This approach includes a set of six tests that were used on an individual basis in previous empirical studies on contagion effects. This set of tests and procedures provides us the possibility of obtaining a greater degree of accuracy in testing the occurrence of contagion effects on international financial markets.

3. Methodology and Data

3.1 Methodology

In terms of research methodology, daily data is used in order to evaluate the contagion effects of six financial crises on stock markets of nine developed countries: Portugal, Spain, Ireland, Greece, France, United Kingdom, Germany, USA and Japan. It should also be stressed that the large majority of this type of research very seldom takes developed countries into consideration as well as daily data. Given their international importance, the six crisis episodes that were studied are: the Mexican crisis (1994-1995), the Asian crisis (1997-1998), the Russian crisis (1998), the Brazilian crisis (1999), the crisis of the September 11 terrorist attacks (2001) and the Argentinean crisis (2001-2002).

The research methodology now presented aims to analyse the contagion effects of the financial crises on stock markets of developed countries. For this purpose, empirical tests that were previously used, by and large, on an individual basis, are now jointly applied in order to provide a more accurate analysis. To contrast our findings with those from previous studies our tests also assume normality[2]. The following tests were used: (i) correlation tests; (ii) Kolmogorov-Smirnov tests; (iii) extreme value tests; (iv) tests based on the estimation of Cointegrated Vector Autoregressive (CVAR) models.

We begin by calculating the correlation coefficients of share profitability in order to capture the co-movements among the markets in the short run. If the correlations increase significantly, the markets will not be following the relationships dictated by the normal changes in fundamental factors. On the contrary, if the correlations do not increase in a significant way, the markets will simply be reacting to common shocks. On the one hand, these elements make it possible to test if the correlations are different from zero, both individually and jointly. For this purpose the statistical significance of the Pearson correlation coefficient is tested and the maximum likelihood ratio is calculated (Pindyck and Rotemberg, 1990). On the other hand, the correlation coefficients are

[2] For comparative purposes this study assumes normality. However, it is worth noting that because linearity and the quadratic utility function seemingly are inconsistent with the behavior of financial series some recent research do not assume them and have developed and applied alternative models. However, financial theory also finds strong justifications for the assumption of normality. In relation to the CAPM, for instance, Merton (1973) assumes continuous portfolio revisions, which leads to end of period lognormal returns and to an instantaneous CAPM. Since we use high frequency data and since during crisis periods portfolio adjustments are frequent, our assumption of normality is valid and allow us to contrast our results with other studies.

compared, in order to find out if the values are significantly higher in the crisis periods as compared to calm periods.

As proposed by Forbes and Rigobon (2002), the t test is used to analyse the heteroscedasticity in two sub-samples. Kolmogorov-Smirnov tests are used in order to find out if the statistical characteristics of the distribution function of the sample change, in a significant way, in the crisis period in comparison with the calm period. We take into consideration the characteristics of the probability distribution of the series in the crisis period in relation to the total of sample period used in this study in order to assure a greater robustness for this kind of test. Moreover, extreme value tests are done to identify which part of the total observations is located in the extreme percentiles of 5% and 95% of the probability distribution. This kind of data provides us with the possibility of knowing if the crisis period was characterised by a greater frequency of extreme profitability. However, this evidence, in itself, does not prove the existence of contagion effects. It is necessary to verify, simultaneously, the extreme observations in several markets considered in our sample. For this reason, we proceed with the analysis of the temporary association of the extreme observations. As happens with the Kolmogorov-Smirnov tests, extreme value tests are applied only in the periods of crisis (so, they were not applied taking into account the total sample period).

In order to complete the tests previously mentioned, we proceed with the application of tests based on the Cointegrated Vector Autoregressive (CVAR) model estimation procedures: (i) the selection of an initial model specification, (ii) the study of the integration order of the variables, (iii) the detection of the cointegration relations, (iv) the application of Granger causality tests and (v) the estimation process of the Cointegrated Vector Autoregressive (CVAR) model. In the initial specification of the model, we will take into consideration the relationships established in the economic theory with regards to the contagion effects on international financial markets. In relation to the study of the integration order of the variables, two tests are used: the ADF test (Dickey and Fuller, 1979), and the Phillips-Perron test (Phillips and Perron, 1988). The use of two types of tests can be useful since the null hypothesis of the ADF test may not be rejected, even in the presence of a structural break in the generation process of the data. Besides, as is pointed out by Perron (1989), the use of only one conventional test for detecting unit roots, in a subset of data, may generate losses in terms of the power of the test. These losses may, erroneously, lead to the rejection of the null hypothesis. The number of lags to be considered, in the case of the ADF test, is selected according to the results provided by three information criteria: Akaike, Hannan-Quinn and Schwarz. The maximum number of lags is selected through the use of the decision rule provided by the Bierens criteria. When performing the Phillips-Perron, an estimator of long-term variance of the Newey-West type is used in order to correct heteroscedasticity and autocorrelation in the data.

Regarding the cointegration vectors, these are calculated for the whole period of the sample and also for each of sub-periods of the respective crisis. The Maximum Eigenvalue tests and the trace test (Johansen, 1988, 1991,

1994; Johansen and Juselius, 1990) are used in order to detect the existence of cointegration relationships. The lag of the variables is selected taking into consideration two information criteria: Hannan-Quinn and Schwarz. In the estimation process, we use the largest lag proposed, starting from a maximum lag of eight periods. The use of Granger causality tests provides the possibility of testing the existence of precedence relationships among the stock indices that represent the financial markets in this study. The number of lags to be considered in the estimation procedure is determined according to the use of three information criteria: Akaike, Hannan-Quinn and Schwarz. In order to eliminate spurious estimations, we select the largest lag, starting from a maximum lag of eight periods. Furthermore, the statistical significance of the estimators is tested through the inclusion of further lags.

Finally, we estimate a Cointegrated Vector Autoregressive (CVAR) model. The order of the variables for estimating that model is obtained by a Cholesky decomposition of the covariance matrix. The estimation process of the Cointegrated Vector Autoregressive (CVAR) model complements the other contagion tests that have been referred to, especially by making use of additional forecasting techniques, such as impulse response functions. The analysis of the coefficients of the impulse response functions provides us with the measurement of statistical significance, the magnitude, and the persistence of the impact of an innovation that occurred in another market. Additionally, the proportions obtained through the analysis of the variance decomposition of the forecasting error allow us to identify the degree of exogeneity presented by each of the markets in the study.

3.2 Data

The data used in the study consist of the daily profitability of the stock market indices of nine countries: Portugal (PTE), Spain (SPA), Ireland (IRE), Greece (GRE), Germany (GER), France (FRA), United Kingdom (UK), United States of America (US) and Japan (JAP).

Tabla 1. Indices Included in the Sample

Country	Index	Variable
Portugal	PSI20	PTE
Spain	IBEX35	SPA
Ireland	ISEQ	IRE
Greece	ATG (Main General Index)	GRE
Germany	DAX	GER
France	CAC40	FRA
United Kingdom	FTSE	UK
United States	S&P500	US
Japan	Nikkei	JAP

Tabla 2. The Crisis Period and the Calm Period for each one of the Selected Crisis Episodes

Crisis	Crisis period
Crisis of Mexico	19/12/1994 - 30/03/1995
Crisis of Asia	17/10/1997 - 30/01/1998
Crisis of Russia	06/08/1998 - 15/10/1998
Crisis of Brazil	04/01/1999 - 15/03/2000
Crisis of September 11	14/09/2001 - 31/10/2001
Crisis of Argentina	14/12/2001 - 28/02/2002

Tabla 2. The Crisis Period and the Calm Period for each one of the Selected Crisis Episodes (continued)

Crisis	Calm period
Crisis of Mexico	11/06/1994 - 18/12/1994
Crisis of Asia	02/01/1996 - 30/12/1996
Crisis of Russia	02/01/1996 - 30/12/1996
Crisis of Brazil	02/01/1996 - 30/12/1996
Crisis of September 11	10/07/2000 - 28/02/2002
Crisis of Argentina	10/07/2000 - 29/06/2001

The observations are from the period between 5^{th} January 1993 and 25^{th} November 2004. The profitability was calculated through the first differences of the logarithms of the indices, which were obtained from the Reuters financial information system. In the data selection process, we just consider the observations that are common to the nine indices. This procedure yielded a total of 2,528 observations for each country. In order to preserve the dynamics of the evolution of the indices, several missing values were calculated through linear interpolation. This procedure was used only when there were observations in a minimum of seven out of the nine countries in the sample. This procedure was not used when the absence of more than one observation on successive days was verified, in the same country. This provided us with the possibility of adding observations related to 350 days more. Therefore, the number of 2,878 daily observations per country and a total of 25,902 observations were obtained.

4. Empirical Findings and Discussion

The nature of contagion has been simplified, since the tendency to quantify each of its effects (for example, volatility, probability distribution functions, causality patterns among the markets, and the magnitude and persistence of profitability shocks) has prevailed in the literature until now. Nonetheless, contagion may, simultaneously, originate distinct effects on the multiple parameters that characterises the financial markets.

Consequently, taking into consideration a few "holes" detected in the literature, an innovative methodology is used, particularly based on a large set of tests. The following presentation, of the empirical results, follows the chronological order of the episodes of financial crisis[3]

Table 3. Results of the Granger Causality Tests for the Sample Period

	PTE	SPA	GRE	IRE	GER	FRA	UK	US	JAP	Total
PTE		R	NR	R	NR	NR	NR	R	R	4
SPA	R		NR	R	R	NR	R	R	R	6
GRE	NR	R		R	R	R	R	R	NR	6
IRE	R	R	R		R	R	R	R	NR	7
GER	R	R	NR	R		R	R	R	NR	6
FRA	NR	NR	NR	R	R		R	R	R	5
UK	(R)	NR	NR	R	R	R		R	R	6 (1)
US	(R)	NR	NR	R	NR	NR	R		NR	3 (1)
JAP	R	R	R	R	R	R	R	R		8
Total	6 (2)	5	2	8	6	5	7	8	4	51 (2)

Notes: The markets in columns cause the markets in lines; R and (R) mean that the null hypothesis, which states that the market in the column does not cause the market in the line may be rejected, at a significance level of 5% and 10%, respectively; NR means that the null hypothesis, which states that the market in the column does not cause the market in the line, may not be rejected, at a significance level of 10%.

[3] The tables regarding the results of the cointegration tests, can be obtained from the authors under request.

Table 4 Results of the Correlations Tests

	Correlations tests							
	Calm Period (CP)				Crisis Period (CRP)			
	1%	5%	10%	>10%	1%	5%	10%	>10%
MexicoC.	21	3	2	10	12	3	1	20
AsiaC.	23	3	0	10	28	3	1	4
RussiaC.	23	3	0	10	33	1	0	2
BrazilC.	23	3	0	10	19	5	4	8
Septemb.11C.	31	2	3	0	35	1	0	0
ArgentinaC.	31	2	3	0	24	4	3	5

Regarding the correlation tests, the number of correlation coefficients that are statistically significant, at significance levels of 1 %, 5% , 10% and more than 10%, for the Calm Period (CP) and the Crisis Period (CRP) is presented.

Table 4. Results of the Correlations Tests (continued)

Correlations test				
Variation CRP vs CP				
	1%	5%	10%	>10%
Mexico C.	0	4	0	32
Asia C.	0	12	10	14
Russia C.	0	6	22	8
Brazil C.	0	0	8	28
Septemb. 11 C.	0	1	17	18
Argentina C.	0	0	1	35

4. Results of the Kolmogorov-Smirnov tests (continued)

Kolmogorov-Smirnov test								
	Variations CRP vs. CP				Variation CRP vs. T. P			
	1%	5%	10%	>10 %	1%	5%	10%	>10%
Mexico C.	1	1	0	7	2	1	2	4
Asia C.	4	2	2	1	1	0	2	6
Russia C.	9	0	0	0	6	3	0	0
Brazil C.	3	2	2	2	0	1	0	8
Sept. 11 C.	0	3	1	5	0	5	1	3
Argentina C.	0	0	0	9	0	0	1	8

In relation to the Kolmogorov-Smirnov tests, the number of significant values is presented, when both the CP and the CRP, and the CRP and the total period, are compared, in terms of the distribution of probability functions, at significance levels of 1%, 5% , 10% and more than 10%, for each episode of financial crisis in the study.

5. Results of the Granger Causality test

Granger Causality Test						
	CP			CRP		
	R	(R)	NR	R	(R)	NR
Mexico C.	19	5	48	22	5	45
Asia C.	22	4	46	47	6	19
Russia C.	22	4	46	34	4	34
Brazil C.	22	4	46	43	3	26
Septemb. 11 C.	22	4	46	52	4	16
Argentina C.	22	4	46	35	3	34

The columns R and (R) present the number of market pairs where the null hypothesis, which states that the profitability of a certain market does not precede the other market, may be rejected, at a significance level of 5% and 10%, respectively. The column (NR) presents the number of market pairs where the null hypothesis, which states that a certain market does not precede other market, may not be rejected, at a significance level of 10%.

5. Results of Impulse-Response Function (continued)

Impulse-response function								
	CP				CRP			
		Number of sessions				Number of sessions		
	N.	1	2	>2	N.	1	2	>2
Mexico C.	13	12	1	0	25	16	8	1
Asia C.	18	18	0	0	22	14	7	1
Russia C.	18	18	0	0	0	0	0	0
Brazil C.	18	18	0	0	2	2	0	0
Septemb. 11 C.	18	17	1	0	0	0	0	0
Argentina C.	18	17	1	0	0	0	0	0

6. Percentage of Extreme Values for each Financial Market in the Crisis Period (CRP) and in the Calm period (CP) for each Crisis Episode

	Mexico Crisis		Asia Crisis		Russia Crisis	
	CRP	CP	CRP	CP	CRP	CP
PTE	1.4%	8.1%	16.2%	0.8%	45.1%	0.8%
SPA	4.3%	2.2%	20.6%	0.8%	49.0%	0.8%
GRE	2.9%	0.7%	19.1%	2.1%	41.2%	2.1%
IRE	0.0%	3.7%	16.2%	2.1%	52.9%	2.1%
GER	0.0%	2.2%	22.1%	0.8%	41.2%	0.8%
FRA	4.3%	5.2%	17.6%	0.4%	43.1%	0.4%
UK	0.0%	3.0%	23.5%	1.2%	43.1%	1.2%
US	0.0%	0.7%	16.2%	3.3%	31.4%	3.3%
JAP	11.4%	0.7%	38.2%	2.1%	25.5%	2.1%
Total	24.3%	26.5%	189.7%	13.6%	372.5%	13.6%

The percentage of observations for the Calm Period (CP) and the Crisis Period (CRP), which are defined for each episode of crisis i.e. below the 5% percentile, or above the 95% percentile is presented for each one of the nine financial markets in the sample.

6. Percentage of Extreme Values for each Financial Market in the Crisis Period (CRP) and in the Calm period (CP) for each Crisis Episode (continued)

	Brazil Crisis		*Sept.11C Crisis*		*Argentina Crisis*		*Total*
	CRP	*CP*	*CRP*	*CP*	*CRP*	*CP*	*Period*
PTE	17.6%	0.8%	25.0%	13.6%	4.2%	13.6%	10.0%
SPA	13.7%	0.8%	41.7%	14.4%	10.4%	14.4%	10.0%
GRE	25.5%	2.1%	13.9%	14.0%	0.0%	14.0%	10.0%
IRE	15.7%	2.1%	47.2%	11.9%	16.7%	11.9%	10.0%
GER	13.7%	0.8%	27.8%	8.2%	12.5%	8.2%	10.0%
FRA	17.6%	0.4%	36.1%	9.1%	2.1%	9.1%	10.0%
UK	19.6%	1.2%	41.7%	13.6%	2.1%	13.6%	10.0%
US	21.6%	3.3%	30.6%	17.7%	8.3%	17.7%	10.0%
JAP	5.9%	2.1%	25.0%	11.9%	8.3%	11.9%	10.0%
Total	150.9%	13.6%	289.0%	114.4%	64.6%	114.4%	90.0%

The "Total period" column indicates the reference value that is obtained for the total period of the sample.

7. Percentage of Sessions with Extreme Values associated with the Crisis Period (CRP) and the Calm Period (CP) for each Crisis Episode

	Mexico Crisis		Asia Crisis		Russia Crisis	
	CRP	CP	CRP	CP	CRP	CP
0	88.6%	90.7%	64.7%	95.2%	47.1%	95.2%
1	9.3%	6.3%	18.4%	3.7%	16.7%	3.7%
2	2.1%	2.2%	2.9%	0.2%	6.9%	0.2%
3	0.0%	0.4%	2.9%	0.6%	4.9%	0.6%
4	0.0%	0.4%	2.9%	0.2%	7.8%	0.2%
5	0.0%	0.0%	2.9%	0.0%	2.9%	0.0%
6	0.0%	0.0%	1.5%	0.0%	5.9%	0.0%
7	0.0%	0.0%	2.9%	0.0%	4.9%	0.0%
8	0.0%	0.0%	0.7%	0.0%	1.0%	0.0%
9	0.0%	0.0%	0.0%	0.0%	2.0%	0.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

The percentage of session (in terms of trading days) of the Calm Period (CP) and the Crisis Period (CRP), which are defined for each episode of crisis, where a certain number of markets that is indicated in the first column denotes a profitability that is below the 5% percentile or above the 95% percentile is presented for each one of the nine financial markets in the sample.

7. Percentage of Sessions with Extreme Values associated with the Crisis Period (CRP) and the Calm Period(CP) for each Crisis Episode

Brazili Crisis		Sept 11 C		Argentina Crisis		T. Period
CRP	CP	CRP	CP	CRP	CP	
63.7%	95.2%	51.4%	70.8%	80.2%	70.8%	77.8%
21.6%	3.7%	15.3%	17.9%	9.4%	17.9%	13.0%
4.9%	0.2%	12.5%	5.1%	9.4%	5.1%	4.0%
2.9%	0.6%	8.3%	1.4%	0.0%	1.4%	1.5%
2.9%	0.2%	1.4%	1.6%	1.0%	1.6%	1.4%
1.0%	0.0%	0.0%	1.2%	0.0%	1.2%	0.9%
2.0%	0.0%	6.9%	1.0%	0.0%	1.0%	0.8%
1.0%	0.0%	2.8%	0.8%	0.0%	0.8%	0.5%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
0.0%	0.0%	1.4%	0.0%	0.0%	0.0%	0.1%
100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

The "Total period" column indicates the reference value that is obtained for the total period of the sample

In the Mexican crisis (1994-1995) it was verified that the differences among the values of the coefficients decreased in the crisis period in most of the pairs of countries. The increases were significant, at a significance level of 5%, in only 4 of the possible 36 cases. The Kolmogorov-Smirnov tests indicate that the probability distribution of the generality of the analysed markets did not change in a significant way. The analysis of the extreme values of profitability revealed that the Mexican crisis did not significantly affect the volatility of the markets. The percentage of extreme observations was not very high, both when compared with the calm period and when the whole period was considered. This result is not enough to confirm the existence of contagion, if we consider it as an increase in the temporary coincidence of the extreme observations. During the Mexican crisis, there were a reduced number of temporary coincidences of extreme observations.

In 88.6% of the sessions, none of the markets present values in the extreme percentile and there is more than one market in that situation in only 2.1% of the sessions. Thus, according to the temporary coincidence of the extreme observations, the crisis of Mexico did not originate significant levels of contagion. During calm periods, the performance of the unit root tests does not allow us to reject the hypothesis related to the existence of a unit root in four of the nine markets of the sample. Cointegration relationships were detected, which shows the existence of a long-term balance between the markets. In turn, in the crisis period, substantial changes are not observed either regarding the stationarity of the variables or in relation to the cointegration relationships among the markets. Non-stationary markets subsist. From the 36 cointegration relationships previously detected, 35 subsist. The causality relationships among the markets of the sample did not substantially change when we compared the evolution of the markets, both in the calm period and in the crisis period, and in global terms a slight increase of the number of significant causalities was observed. Thus, 24 causality relationships were detected in the calm period, whereas 27 were observed in the crisis period.

Analysis of the impulse response functions revealed that, during the calm period, from the 72 possible relationships in the sample, only 13 significant relationships were detected. The shocks are generally significant, for just a limited period of time, and they disappear completely at the end of six sessions. During the crisis period, the profile of the impulse response functions changed significantly. The number of significant impacts almost doubled (24), and the persistence of the shocks increased. The analysis of the impulse response functions allows us to conclude that the impact of the variations of the US market on the remaining markets in the sample was reinforced during the crisis period. Variance decomposition confirms that the variations that occurred in the crisis period tend to be largely explained through the innovations that occurred in the remaining markets. Taking into consideration the results obtained through the different tests that were carried out in the analysis of the Mexican crisis, limited evidence regarding the occurrence of contagion effects in the stock markets of developed countries is verified.

In the Asian crisis (1997-1998), the degree of linear dependence among the markets increased in all the sample countries during the crisis period. Twelve significant increases in correlation coefficients, at a significance level of 5%, are detected. A structural break in the relationships between the profitability of the markets is also detected. Thus, there is evidence for contagion in the short term. The Asian crisis originated significant changes in the probability distributions of the markets, taking the calm period as a reference. The Kolmogorov-Smirnov test statistics provided values with significance, higher than 5%, in only three of the nine markets in the sample. However, when we made a comparative analysis with the whole period of the sample, we verified that the crisis had significant effects in only three markets. Thus, we conclude that the Asian crisis had moderate effects on the probability distributions of the profitability of the sample markets. During the Asian crisis all the markets showed a frequency of extreme values of profitability above that which was expected, both when we look at the values related to the calm period, and when we consider the reference values.

The Asian crisis was characterised by higher market turbulence, which is observable through an increase in the number of extreme observations and in the temporary coincidence among those extreme observations and in the calm period, the unit root tests indicate that the variables are stationary and both the maximum Eigenvalue test, and the trace test, suggest that the variables present cointegration relationships. But the situation changed in the crisis period and the unit roots test does not allow us to reject the hypothesis of the existence of a unit root in most of the markets. Taking the calm period as a reference, substantial differences must be stressed in terms of the cointegration relationships. This means that, from the 36 bivariate relationships among the markets in the study, the hypothesis relating to the existence of a cointegration relationship is rejected in 9 cases. These results allow us to conclude that the long-term balance between several markets was broken in the crisis period.

The number of significant causality relationships increased substantially during the period of the Asian crisis when compared with the calm period: they increased from 26 to more than double (53). Analysis of the impulse response functions indicates that the interactions among the markets in the sample were moderate during the calm period. We detected 18 significant shocks with significant persistence of just one period. During the Asian crisis, the interaction pattern among the markets did changed significantly. There was an increase of significant shocks up to 22. The persistence of the shocks also increased and in terms of the variance decomposition of the forecasting error, comparative analysis between the calm period and that of the crisis, allows us to conclude that the degree of exogeneity decreased during the crisis period. Thus, using the coefficients of the impulse response functions, and the proportions of the variance decomposition of the forecasting error, we conclude that markets lost autonomy during the Asian crisis.

The evidence obtained through the (joint) application of (six) tests previously mentioned and that were included in the research methodology, allowed us to detect the existence of significant contagion effects on the stock markets

of the developed countries considered in the study. During the financial crisis in Russia (1998-1999), an increase in almost all the correlation coefficients was observed. The data revealed a structural break in the relationships between the profitability of the share indices, which constitutes partial evidence of contagion, in the short term. The crisis was characterised by an increase in the frequency of extreme profitability and by a very strong association between the extreme observations, and in the calm period, the markets of the sample were characterised as being stationary and presenting cointegrating relationships, in both cases without exception.

In the crisis period, some changes in the stationarity of the variables were rejected, and, in 4 out of the 9 variables, we cannot reject the hypothesis related to the existence of a unit root. Despite the changes, and according to Johansen's Maximum Likelihood tests, all the balance relationships subsist in the long term. The number of causality relationships increased, from 26 in the calm period, to 38 in the crisis period. The impulse response functions indicate that, during the calm period, the number of interactions was reduced and moderate. The Russian crisis deeply affected the coefficients obtained through the use of the forecasting technique: the impulse response functions. During the crisis period, we observed that all functions were not significant anymore, including the one that revealed significant relationships between the countries in the calm period.

The variance decomposition technique shows that the changes that occurred in the crisis period tend to be largely explained by the innovations that occurred in other markets. Furthermore, the explanatory capacity of the countries, in relation to their own variance, tends to decrease in the crisis period. These patterns signal a decrease in the autonomy of the generality of the markets during the crisis period. As was previously revealed for the Asian crisis, the results obtained through the use of the battery of tests allow us to verify the existence of strong contagion evidence in the stock markets in the study during the Russian financial crisis as well. With regards to the Brazilian crisis (1999), some increases in correlations during the crisis period were detected. Yet, such increases are not statistically significant, *i.e.,* from the 36 possible cases there were only 8 cases where the increase in correlation was statistically significant, this being, nevertheless, at 10% significance level.

The crisis of Brazil caused a moderate increase in the frequency of extreme observations. Taking as reference the whole sample period, this affected all the developed countries in the sample with the exception of Japan. During the Brazilian crisis, the time coincidence among the extreme observations increased in a moderate way, both in the calm period and in the entire sample period. In more than 85% of the sessions, there was, at the most, 1 market with extreme profitability. In 6.9% of the sessions at least four markets showed extreme profitability.

A moderate increase was verified in terms of the frequency of extreme observations and in the calm period, all the developed markets of the sample were shown to be stationary. Besides, the existence of cointegration between

the variables allows us to infer the existence of balanced relationships in the long term. Nonetheless, during the Brazilian crisis period, the stationarity tests allow us to verify the occurrence of significant changes. The ADF test does not allow the rejection of the hypothesis of existence of unit roots in 8 of the 9 markets.

Nevertheless, the long-term relationships did not change in a substantial way and, from the 36 cointegration relations detected during the calm period, 33 subsisted. Through a comparative analysis between the calm period and the crisis period, an increase in interaction among the stock markets is detected. This is observable by the increase in the number of causality relationships, which increased from 26 to 46, at a 10% significance level. During the calm period, from 72 possible cases, the coefficients of the impulse response functions revealed 18 significant reactions to external shocks. For all the shocks, the significance persists for one period only.

The Brazilian crisis caused a significant change in the coefficients obtained through the simulation of impulse response functions. During the crisis period, only 2 significant cases of interaction between markets were detected. The variance decomposition of the forecasting error of the Cointegrated Vector Autoregressive (CVAR) model estimation allows us to see that the relationship between the markets changed in a significant way during the crisis period. From the joint analysis of the impulse response functions and that of the variance decomposition, we concluded that the autonomy of the markets decreased during the crisis period. Still, it must be stressed that, as happened with the Mexican financial crisis, and considering all the results from the tests, in the case of the Brazilian crisis, limited evidence of contagion was also found.

The September 11 terrorist attacks originated a financial crisis that was characterised by a substantial increase in the correlation coefficients. These results are consistent with the observation of contagion effects. Taking into consideration the results of the Kolmogorov-Smirnov tests, several changes occurred during the crisis. The correspondent statistics do not present any value with a significance value less than 1%, either when the crisis period is compared with the calm period, or when the whole sample period is considered. About half of the observations were located in the extreme range of the probability distribution.

It must be stressed that, on average, it was observed that almost 3 markets, per session, reached negative profitability, although a unitary value was expected. During the September 11 crisis period, the association among the extreme observations was very high. In about 12.5% of the sessions, at least four of the nine markets of the sample reached extreme profitability. Regarding the calm period, by making use of the Johansen procedure, the existence of cointegration relationships was detected. In the process of detecting unit roots, the ADF test and the Phillips-Perron test allow us to confirm that the variables are stationary. Anyhow, in the crisis period, significant changes were observed in terms of the behaviour of the variables. With respect to the stationarity of the variables, in most of the variables the hypothesis related to the existence

of unit roots was not rejected. The tests suggest that the markets of Spain, Ireland, France, United Kingdom and Japan are order-one integrated. Furthermore, the German and Japanese markets are order-two integrated, and that of Greece is order-four integrated.

We also detected the existence of 36 cointegration relationships among the 9 financial markets in the study. Furthermore, 9 bivariate relationships among non-cointegrated variables were detected. Taking the calm period as a reference, in the crisis period, several established relationships among the variables were broken. The individual factors, *i.e.,* the ones that are specific to each market, seem to have an increasing importance in the evolution of profitability. The number of Granger causality relationships increased substantially during the crisis period when a comparison with the calm period is made. The systematic influences increased from 26 to 56 between the two referred periods. The change that was observed was in the sense of a substantial increase in the interaction levels among the generality of the markets.

During the calm period it was possible to observe 18 significant reactions to international shocks. They were detected through the simulation of the coefficients of the impulse response functions. In general, the significant reactions assume a short-term nature, for one period only. At the end of 4 sessions, the current effects of innovations in other markets disappear completely. Yet, the impulse response functions that were calculated for the crisis period did not allow us to verify any significant reactions among the nine developed countries.

In spite of the fact that this result is similar to that verified in the Russian as well as in the Brazilian periods od crises, analysis of the impulse response functions revealed that the September 11 crisis assumed a quite different nature. While in the Russian and Brazilian cases, the impulse response functions provided considerable values, whose statistical significance was reduced due to the high volatility level, in the September 11 crisis, the impulse response functions reached very low values (close to zero) in almost all the coefficients that were simulated. Thus, it must be stressed that the technique of impulse response functions is not adequate for retaining the lagged effects, in crises with short durations, such as the September 11 one.

Taking into consideration the proportions obtained through the variance decomposition technique, during the crisis of September 11, the stock markets of the developed countries lost autonomy. The relative importance of innovations in the explanation provided with the forecasting error of the Cointegrated Vector Autoregressive (CVAR) model decreased in most of the countries, both when comparison was made during the calm period and when the whole period was considered. According to previous results, the crisis of September 11 shows significant evidence of contagion effects on the developed markets. This fact reveals the importance of this individual crisis episode, as well as those of the Asian and Russian crises, confirming the impact of financial crises, with different geographical origins, on the behaviour of the stock market indices of the developed countries, in the context of an international financial crisis.

In chronological terms, the last episode of international financial crisis in the study is that which took place in Argentina, where it was verified that the levels of linear dependence among the markets did not change in a substantial way. The crisis of Argentina did not originate significant effects in terms of changing the probability distributions of the markets. Kolmogorov-Smirnov tests reveal that the probability distribution of all markets, during the crisis period, was not significantly different from the one that was evident during the calm period. By comparing the whole sample period, the conclusions are similar for almost all the markets. Thus, the occurrence of contagion effects was not verified.

Summing up, the crisis did not have a significant impact on changing the frequency of extreme observations. On average, during the whole crisis period, 65% of the markets, per session, reached extreme profitability when the expected value was one. Most of the countries revealed a frequency of extreme observations below the average. The degree of coincidence among the extreme values of profitability was very low. During the crisis period, it was possible to observe at lest four markets with extreme profitability in only 1% of the sessions. During the calm period, the variables were stationary and cointegrated, This situation changed during the crisis period. This way, the ADF and Phillip-Perron tests do not allow us to reject the existence of unit roots in five developed countries. Despite the changes that were observed in terms of the stationarity of the variables, the cointegration tests continued to indicate the existence of stability relationships among the markets. Johansen's Maximum Likelihood tests allowed us to reject the hypothesis of inexistence of cointegration relationships among all the markets.

Comparative analysis of the causality patterns suggests that the relationships between the markets in the sample changed in a significant way, increasing from 26 to 38, taking the calm period as a reference. During the calm period, it was possible to observe 18 significant reactions through the analysis of the impulse response functions. During one period, the significant reactions assumed a short-term nature, with only one exception. For the Argentinean crisis, the coefficients of the impulse response functions did assume values close to zero, in almost all the cases. Again, we stress that the technique of impulse response functions is not adequate to capture the lagged effects of shocks, in short periods of time, as it was the case of Argentina.

A comparative analysis between the calm period and the crisis period makes it possible to detect substantial changes in terms of relationships among the markets. In the crisis period, the variances tend to be largely explained by the innovations that occurred in the remaining markets. From this we did infer that, independence among the markets, decreased during the Argentinean crisis. As was observed in the financial crises of Brazil and Mexico, very limited evidence of the occurrence of contagion effects were revealed in the Argentinean crisis. In order to better understand the implications of contagion effects on the financial markets of developed countries, a concise and comparative discussion of the results obtained for each of the episodes of financial crises was also carried out. First, the episodes that show strong evidence of contagion effects

are discussed. Second, the episodes that show limited evidence are discussed as well.

In the Asian and Russian crises, strong contagion effects were detected, both in the short and in the long term. This has implications in terms of the increase in frequency and in the association of extreme profitability. The test for change in the probability distribution was the only one that did not show the existence of contagion effects. All the performed remaining tests did support the hypothesis related to the decrease, in independence, of the stock markets. According to this, the crisis of Asia was characterised by an extreme level of contagion. Despite being significant, the results of the tests related to the Russian crisis did indicate a different nature, in the sense that the correlation tests and the causality tests did allow to verify the existence of significant contagion effects in the short term. This implies the observance of significant changes both in terms of the probability distribution and of the increase in frequency, as well as in the association of extreme profitability. However, the cointegration tests do not support the detection of a structural break in long-term relationships. Overall, the results of the tests provide evidence of strong contagion effects derived from the Russian crisis, albeit they did not reach an extreme level.

In the September 11 crisis, the contagion effect was of a short-term nature. This was observed through the application of correlation tests and Granger causality tests. It was also observable in terms of the increase, in incidence and in association, of extreme profitability, whose the results were obtained from the extreme value tests. Taking into consideration the results of the cointegration tests, a long-term nature was identified. Nevertheless, by examining the tests, based on the impulse response functions, the pattern of transmission of profitability, among the markets, is not so clear. According to the results of the Kolmogorov-Smirnov tests, the data generation processes did not change significantly. Consequently, we may conclude that, during the September 11 crisis, contagion effects were strong, but they did not reach an extreme level.

The results of the tests also indicate that, the crisis in Brazil, was not as contagious as the crisis in Russia. The incidence of contagion in the short term was not clear. The correlation tests pointed to the inexistence of contagion, whereas the causality tests indicate that a significant change in the patterns of transmission was verified. The Kolmogorov-Smirnov tests, although indicating a moderate degree of change in the probability distribution of the profitability, are not robust in light of the changes in the comparison parameters. Furthermore, according to the cointegration tests, contagion is not verified in the long term. Also, the simulation of impulse response functions did not allow us to detect significant changes in the patterns of shock transmission among the markets. After evaluating all the evidence related to this episode, we consider that the evidence of contagion effects is limited.

Regarding the Argentinean crisis, and with the exception of the extreme value statistics, the results of the tests are very similar to those obtained for Brazil. The causality tests indicate changes in terms of the relationships among

markets that are consistent with the occurrence of contagion effects in the short term, while the correlation tests do not support this hypothesis. The tests neither allow the clear identification of contagion patterns nor support the fact that this phenomenon had repercussions in the long term. Thus, evidence of contagion is limited for the Argentinean crisis. In relation to the Mexican crisis, and according to the results of most of the tests, there is no significant evidence of contagion, either in the short or long term. The changes in the probability distribution of profitability in the markets were not significant. Moreover, during the study period, there were no significant changes in terms of frequency or association of the extreme observations.

5. Conclusions

This study presents an innovative contribution, since it proposes and uses a research methodology that is supported by a large set of tests (jointly applied), which allowed a more accurate evaluation (as compared to previous studies) of the contagion effects, from financial crises, on the financial markets of nine developed countries, from 1993 to 2004. Similarly, after detecting a confusion in the literature about the ways on how to test contagion effects, a study, based upon financial markets of developed countries, was carried out making use of a complete and, in fact, widely used (mostly per se) set of tests: correlation tests, Kolmogorov-Smirnov tests, tests of extreme value, and tests based on the estimation of Cointegrated Vector Autoregressive (CVAR) models.

The results revealed the importance of contagion effects on stock markets in developed countries during the crises in the 1990s. They are particularly interesting, since they provide important and straightforward insights that contribute to a better understanding of the processes of international risk diversification. During periods of crisis, *i.e.,* when diversification of the financial asset portfolios is most needed, the incorporation of information about contagion effects is essential for the design of arbitrage strategies that aim to minimise the risks inherent in the composition of portfolios, of international financial assets, namely in developed countries.

The occurrence of contagion, understood as a co-movement in profitability, was detected for the crises of Asia, Russia and September 11. As to the Russian crisis, the results pointed to the ratification of a definition of contagion that essentially considers the change in the statistical processes for generating prices. If we take into consideration the definition of contagion that is based on a significant increase in the frequency as well as in the association of extreme profitability in the financial markets, contagion effects were also detected in the crises of Asia, Russia, Brazil and September 11. At any rate, it should be underlined that these contagion effects, expressed through the international transmission of shocks, were also detected in all episodes of financial crisis, although with different intensities. Based upon the results from all tests here applied, we can conclude that there was one case of very strong contagion (Asian crisis), two cases of strong contagion (Russia and September 11), two cases with limited evidence (Brazil and Argentina) and one with no significant contagion (Mexico).

The prevalence of the contagion phenomenon in developed countries also means that a justification exists for a multilateral coordination of investment policies in order to limit the propagation of profitability shocks. It makes sense to prevent the conditions of vulnerability that are associated with contagion, both in terms of the fundamentals as well as of the investors' behaviour. Consequently, it is also very important to design adequate supervision policies which should aim to improve the risk management of the financial sector and to reinforce the transparency and the stability of the financial markets, taking into consideration not only the solidity of the fundamentals, but also the role assumed by the expectations of the investors in relation to these fundamentals.

Another important finding of this study was that, in terms of detecting contagion effects, several differences were found between the results obtained through the application of a large set of tests (jointly applied) and the results obtained using tests applied per se (or jointly applied with one or two more, as in the vast majority of the studies found in the literature). Also, the inferences made through the exclusive use of the variance decomposition of forecasting error tend to confirm contagion effects. On the contrary, if we consider only the Kolmogorov-Smirnov results, this evidence is much reduced. Thus, and this is extremely important, the results suggest that the conclusions related to contagion effects depend, mostly, on the selection of the tests being used and, also, on the definition of contagion itself. Likewise the case of any research, our study opens many opportunities for further comparative research on the impacts of financial crises. Most of the statistical tests used in our paper followed methodologies commonly applied in the literature, which are based on the assumption of normality. This suggests future studies testing contagion applying models from the ARCH family, extreme value theory and quantitative behavioural finance.

It would be also important to develop investment strategies that allow an adequate/prompt reaction to the transmission of shocks between markets. Moreover, further research about contagion in relation to other categories of financial assets is needed. Finally, another interesting line for future research is that related to the study of the contagion phenomenon by using high frequency data at an intra-day level; this would enhance current knowledge and understanding about the relationships between the contagion and the microstructure of the markets, *i.e.,* between the process of price discovery and the transmission of profitability shocks in financial markets.

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