▪ Advances in Scientific and Applied Accounting, ▪ ISSN 1983-8611 ▪ São Paulo ▪ v.14, n.2 ▪ p. 067-079 ▪ May. / Aug. de 2021.
▪ DOI: 10.14392/asaa.2021140203

ASAA

Financial contagion and interdependence between Latin American and United States markets

Paulo Fernando Marschner, Paulo Sergio Ceretta, Adriano Mendonça Souza, Leonardo Gress de Lima

Universidade Federal de Santa Maria. Santa Maria-RS, Brazil.

[1]paulofernandomarschner@hotmail.com
[2]ceretta10@gmail.com
[3]amsouza.sm@gmail.com
[4]leogress@hotmail.com

Edited by:
Orleans Silva Martins
Paulo Roberto da Cunha

Abstract

Objective: The aim of this study is to analyze the existence and magnitude of financial contagion and interdependencies between the Latin American (Argentina, Brazil, Chile, Mexico and Peru) and United States (U.S.) stock markets.
Method: vector autoregressive (VAR) models were applied to stock markets index returns in three periods: pre-crisis, crisis and post-crisis.
Results: after estimating, it was observed that in the three sample subperiods (pre-crisis, crisis and post-crisis) vector models were adjusted with different lag levels, VAR(1), VAR(3) and VAR(1), respectively, showing that in the crisis period the endogenous variables affect the system of simultaneous equations for up to three lag periods, and in the other subsamples for only one period. The main results showed that: i) the pre-financial crisis period is characterized by insignificant levels of interdependence between the Latin American and U.S. markets; ii) during the crisis period, the American market had the power to explain the variance of most Latin American markets; and iii) after the crisis, the ties between the markets in that region and the American market remained in place, albeit to a lesser extent.
Contributions: The evidence found in this research expands the literature and presents new evidence on the relationship between Latin American and U.S. markets. The role of the American market on some markets in this region during the crisis, as well as the post-crisis relations, were not fully elucidated by the previous literature.

Keywords: Financial Contagion. Emerging Markets. Financial crisis. Latin America.

How to cite
Marschner, P. F., Ceretta, P. S., Souza, A. M., & de Lima, L. G. FINANCIAL CONTAGION AND INTER-DEPENDENCE BETWEEN LATIN AMERICAN AND UNITED STATES MARKETS. Advances in Scientific and Applied Accounting, 14(2), 054–066/067. https://doi.org/10.14392/asaa.2021140203

Received: September 23, 2020
Revisions required in: October 17, 2021
Accepted: October 18, 2021

Introduction

The spread of a crisis that occurred in one economy to another is known in the literature as the contagion effect. In recent decades, several studies have emphasized the relevance of this effect due to its importance in resource allocation and risk management decisions, and even though there is no universally accepted definition for contagion, several definitions have been proposed in the literature to identify its existence (Ribeiro & Hotta, 2013). Although broad and diverse, these proposals characterize financial contagion as a significant increase in the relationships between performance indices during a period of crisis compared to relationships in periods of economic stability (Forbes & Rigobon, 2001; Ribeiro & Hotta, 2013; Oliveira, Albuquerque, & Carvalho, 2019).

Unlike the concept of contagion, interdependence is the phenomenon in which price movements in a stock market influence the behavior of prices in another market (Pimenta Jr., 2004). In other words, interdependence reflects the level of relationship between markets that occurs in a period of stability. Soydemir (1997) argues that contagion between markets is, then, a self-reinforcing effect of interdependencies, as local investors react in a conditioned way due to external information, such as crises, for example.

Crises affect a wide range of countries and territories with such severity and simultaneity that the existence of a pattern is a hypothesis that arises spontaneously (Marçal, Pereira, Martin, & Nakamura, 2011). According to Oliveira et al. (2019) it is perfectly plausible to assume that economies with more intense similarities or relationships, such as economic blocks, receive a greater and homogeneous impact from these events. These phenomena are caused by the correlation existing in these markets and are relevant when choosing an investment portfolio according to the fundamentals presented by Markowitz (1952).

It is possible to verify in the literature that the grouping of countries by economic or geographic criteria attracted the attention of researchers, and it is possible to group these studies in the countries that make up the BRICS (Aktan, Mandaci, Kopurlu & Ensener, 2009; An & Brown, 2010; Bergmann, Securato, Savoia & Contani, 2015; Wang, Xie, Lin & Stanley, 2017; Nashier, 2015; Oliveira et al. 2019), the Asia-Pacific region (Ahmed & Huo; 2018; Ahmed & Huo, 2019; Ribeiro & Hotta, 2013), Latin America (Pimenta Jr, 2004; Moterri & Mendes, 2005; Chuliá, Guillén & Uribe, 2017; Davidson, 2020; Fortunato, Martins & Bastian-Pinto, 2020), and studies with mixed samples (Pimenta Jr. & Famá, 2002; Marçal, et al. 2011; Farias & Sáfadi, 2010; Zorgati, Lakhal & Zaabi, 2019).

Although the American market is the most influential market in emerging economies, it is known that dependence on Latin American markets tends to be considerably greater due to macroeconomic factors and trade links (Marçal et al. 2011; Cardona, Gutiérrez, & Agudelo , 2017). Thus, it is possible that the contagion effect has occurred and accentuated the interdependence between Latin American countries and the U.S. This perspective was documented by Davidson (2020), however this study considers only the largest markets in this region and does not analyze the behavior of these markets after the financial crisis, disregarding that after 2009 developed markets tend to be more influenced by emerging markets (Samarakoon, 2011).

These circumstances clearly limit the global understanding of relations between Latin America and the U.S., especially after the 2008 financial crisis. Furthermore, interdependence and contagion effects may not always occur in the expected direction in the financial market (Santos, Gaio, Pimenta Junior & Cicconi, 2019). Considering this context, the objective of this research is to analyze the existence and magnitude of the contagion effect and the interdependencies between the Latin American and U.S. stock markets.

To achieve the research objective, data from the main stock market index for five countries in Latin America (Argentina, Brazil, Chile, Mexico and Peru) and the U.S. were collected. Vector autoregressive (VAR) models for three periods were estimated: i) pre-crisis, ii) crisis and iii) post-crisis, and impulse response functions and variance decompositions were generated. The main results showed that: i) in the pre-financial crisis period the levels of interdependence between the Latin American and U.S. markets were insignificant; ii) during the crisis period, the U.S. had an explanatory power for the variance of most Latin American markets; and iii) after the crisis, the ties between the markets in this region and the American market remained in place, but to a lesser extent.

The results of this research offer some contributions to the literature. In relation to previous studies, in addition to corroborating witch pre-financial crisis evidence, they increase the findings on the effect of the crisis in Latin America, and document the impacts that occurred after the crisis, a context little explored in the markets of this region. In managerial terms, these results can be useful for national and international investors, as well as for risk managers interested in an adequate allocation of capital in the assets that make up their investment portfolio. As the need for a better risk control system for investors is evident (Santos, et al. 2019), governments and monetary authorities that seek subsidies for possible regulations or political-economic intervention strategies, in this case, to minimize exposure from emerging markets to contagion risk, may also benefit from this evidence.

2 Literature review

Considering financial contagion as a significant increase in the relationships between performance indices during a period of crisis compared to relationships in periods of stability, a logical interpretation is that economically weak countries are at greater risk of being infected and facing economic crises in periods of turbulence. The last few decades have been marked by several crises, including the colapse of the American market in 1987 (King & Wadhwani, 1990), the Mexican peso crisis in 1994, the Asian crisis in 1997, the Russian crisis in 1998, the Brazilian crisis in 1999, the fall of the Nasdaq in 2000, the Argentine crisis in 2001 (Forbes & Rigobon, 2001; Filleti, Hotta & Zevallos, 2008) and the last financial crisis originated in the U.S. in 2008 (Lee, 2011).

The occurrence of these crises increased the concern of political authorities and investors, causing the debates on the subject to become more intense. Simultaneously, several surveys were conducted in order to verify the contagion effect or the interdependence of stock markets, most often grouping countries by economic or geographic criteria. In the countries that make up the BRICS, Aktan et al. (2009) indicated that the U.S. market has a significant effect on all countries in that region on the same trading day. An and Brown (2010) report that among these markets, only China has a relationship with the U.S. Bergmann et al. (2015) also analyzed the financial contagion of markets in this region with the U.S. market, as well as other markets in the European Union (EU), and found evidence of the contagion effect in both markets. Other works from this region include those by Nashier (2015), Wang et al. (2017) and Oliveira et al. (2019), all being in favor of the existence of interdependencies between these countries and the U.S.

The markets in the Asia-Pacific region also caught the researchers' attention. Ahmed and Huo (2019) looked at the relationship between the Chinese stock market and other Asian markets and found that price pass-on components and volatility are different during stable and financial stress periods. They also found that in periods of high prices the Chinese market has a strong impact on Asian markets. These signs of integration were also observed between Chinese and African actions (Ahmed & Huo, 2018). Based on a canonical model, Ribeiro and Hotta (2013) observed the contagion effect in a group of Asian countries (Hong Kong, India, Japan, Indonesia, Korea, Singapore and Taiwan), and indicated that India and Indonesia are strongly affected by the block formed by the other countries in the region.

Latin American markets were also analyzed. Pimenta Jr (2004), for example, found no evidence of interdependence between Nasdaq and the stock markets of Argentina, Brazil, Chile and Mexico. Moterri and Mendes (2005) also analyzed the relationship between Latin American markets and the U.S., and concluded that only a portion of the observed interdependencies between Latin American markets results from the influence of the American stock market. Although Chuliá et al. (2017) argue that dependence on Latin American markets tends to be considerably weaker when compared to other emerging countries, Davidson (2020) notes that during the global financial crisis, there is evidence of contagion spreading abruptly from the U.S. to Brazil and Argentina, demonstrating that contagion only manifested itself in the recent global financial crisis.

Other studies considered mixed samples. Pimenta Jr. and Famá (2002) found that the levels of interdependence among the eight largest capital markets of emerging countries in Latin America and Southeast Asia were still not consistent. Unlike what was found by Marçal et al. (2011), who a decade later found evidence in favor of the regional contagion hypothesis that possibly spread the Asian crisis to Latin America. Farias and Sáfadi (2010), in a wide sample of emerging and developed economies, found that the Brazilian market exerts a strong influence on the Russian and Chinese markets, as well as that the American market exerts influence on the English and Japanese markets. Zorgati et al. (2019) investigated the contagion effect and its intensity in five American countries (Brazil, Argentina, Mexico, Canada and U.S.) and nine Asian countries (Japan, Hong Kong, India, Australia, Indonesia, Malaysia, Korea, China and Singapore) from 2003 to 2011, finding evidence of the contagion effect in all American markets and most Asian markets.

These studies revealed that, according to some level of interdependence, the American market affects other markets. The contagion effect is also observed in most emerging markets during the 2008 financial crisis. One of the reasons for the strong impact of the 2008 crisis on stock markets was through firms. In a comprehensive study involving developed and emerging markets, Borges, Pimenta Júnior, Ambrozini and Rodrigues (2018) showed that there was a change in the capital structures of companies due to the 2008 international financial crisis. These changes occurred due to the impact of the crisis on liquidity of the international financial system credit, which limited companies debt capacity, causing a drastic reduction in its value.

However, unlike other emerging markets, Latin Americans are strongly linked to the U.S. due to trade and capital flows, cultural proximity, time zone and macroeconomic effects. In addition, Latin American stock markets have become more important for portfolio investments around the world as they offer variety in terms of size, development and economic ties to the U.S. (Cardona, et al. 2017). Another feature that can be observed in the literature is the lack of evidence on Latin American markets after the 2008 financial crisis. These characteristics imply the need for a greater understanding of how Latin American markets behave with each other and with the U.S.

VAR models are suitable for analyzing the relationship between stock markets as they allow the visualization of contagion between the variables included in the model when an external shock is imputed to innovations, in addition to showing the relative importance of each variable in itself and in the others. Some works that use VAR modeling to verify contagion and interdependencies include those by Pimenta Jr. (2004), Pimenta Jr. and Famá (2002), Dooley and Hutchison (2009) and Farias and Sáfadi (2010), for example.

3 Data and method

In this study, daily closing series of five Latin American markets index – the Bovespa Index of Brazil (Ibovespa), the Precios y Cotaziones Index (IPC) of Mexico, the Merval Index (Merval) of Argentina, the Selective Stock Precio Index (IPSA) of Chile and the General Index of the Stock Exchange of Lima (IGBVL) of Peru - were used. For the U.S. market, the Standard & Poor's 500 Index (S&P500) was chosen. Data were collected from 01/01/2002 to 12/31/2018, totaling 17 years.

The dates for which the value of any index was not available were eliminated, leaving a total of 3900 daily observations. These series were then segregated into three periods:, pre-crisis period, from 01/01/2000 to 11/30/2007, with 1385 observations; crisis period, from 12/01/2007 to 06/30/2009, with 360 observations; and post-crisis period, from 07/01/2009 to 12/31/2018, with 2155 observations. These sub-samples were selected based on the dates of the Business Cycle Dating Committee of the National Bureau of Economic Research. This period tends to be robust enough to reveal existing relationships between markets. Although this study uses the 2008 crisis as a reference, the period collected covers the reflection of a wide range of crises that occurred, such as Brazilian in 1999, the fall of the Nasdaq in 2000, the Argentine crisis in 2001 and the last financial crisis in 2008. From the original data, the series of returns were calculated, if X_t is the value of the index at instant t, the log-return or return is given by:

$$R_t=\Delta \ln X_t=\ln(X_t)-\ln(X_{t-1}) \quad (1)$$

To capture the contemporary effects and the short-term relationships between the variables, an VAR model was used. The VAR model was initially proposed by Sims (1980) and its main advantage is the possibility of estimating several variables simultaneously, avoiding the problems of identifying parameters in multi-equational models. The VAR model of order (*p*) is represented in equation 2.

$$Z_t = \sum_{i=1}^{p} A_i Z_{t-1} + V + e_t; \quad p = 1,2,3 \ldots \quad (2)$$

In (2), Z is the matrix of the original variables. Z_{t-1} is the matrix of the original variables with p lags. A it is the matrix of the coefficients, V is the vector of the intercepts, $e_t=(e_{yt},e_{zt})$ are the innovations that must present the characteristic of white noise and k-dimensions so that E $(e_t)=0$; $E(e_{yt}.e_{zt}) = \Sigma$ and $E(e_{yt}.e_{zt})=0$ to $s\neq t$ .For the implementation of the VAR model it is necessary to perform the unit root tests because stationarity is a necessary condition to adjust a stable model that allows studying the short-term relationships between the variables (Senna & Souza, 2016). For this, the Augmented Dickey Fuller tests proposed by Dickey and Fuller (1981) and the KPSS test proposed by Kwiatkowski, Phillips, Schmidt and Shin (1992) will be applied. To select the number of lags of the VAR(*p*) model, an auxiliary VAR is adjusted, with an arbitrary number of lags ranging from p = 1, ..., p = 8, and in this model, five tests/criteria will be applied to select the best model: Sequential LR statistical test modified at 5% significance level, Final prediction error test (FPE), Akaike criterion (AIC), Schwarz criterion (SBIC) and Hannan-Quinn criterion (HQIC). The model that presents the lowest values for these statistics will correspond to the number of lags used in the final model.

VAR modeling, although intuitive, requires caution in the decomposition used in the generation of the autocorrelated innovation vector and in the process of ordering the variables. The Cholesky decomposition has wide appeal in the literature for the dynamic effects provided by the variable orthogonalization method. This procedure used in the estimation attributes the entire systemic effect to the first variable in the model, and changes in the order of variables in the VAR modeling can cause changes in the impulse response function and in the variance decomposition (Vartanian, 2012; Senna & Souza, 2016).

Due to the systemic effect attributed to the first variable used in the estimate, it is recommended to order them according to the degree of endogeneity (Vartanian, 2012). Variables with greater causality must be inserted at the beginning of the sequence and variables with lesser causality at the end of the sequence. This ordering will be determined by the Block Exogeneity test (VAR Granger Causality/Block Exogeneity Wald Tests). For each equation in the VAR model, the Wald statistic tests the significance of each of the other variables in the equation. The total value of the variable statistic demonstrates the significance of all other endogenous variables in the equation. Thus, the series with the lowest statistical value refers to the variable with weak endogeneity and the one with the highest value can be characterized by strong endogeneity (Vartanian, 2012).

After validation of the model, analyzes of the impulse response function and variance decomposition are performed. The first verifies the magnitude of contagion between the variables included in the VAR model when an external shock is imputed to the innovations, represented by the period of time that the variable that received the external shock will take to return to its stability, and the last shows the relative importance of each variable in itself and in the others that make up the system. The impulse response functions will be generated from the Cholesky decomposition that uses the inverse of the Cholesky factor of the residual covariance matrix to orthogonalize the impulses. The variance decomposition is also based on this decomposition, which implies reproducing the same reasoning as the impulse response functions.

4 Results and discussions

To confirm the stationary behavior of the log-returns, stationarity and unit root tests were applied in the time series, in each of the subsamples. The critical values of the ADF test reject the unit root null hypothesis in all cases. This result was confirmed by the KPSS test, whose critical values did not reject the null hypothesis of stationarity. Therefore, the log-returns meet the stationarity assumptions, enabling an adequate estimate of the VAR models.

Table 1. Stationarity and unit root tests.

	Pre-crisis		Crisis		Post-crisis	
	ADF (t-stat)	KPSS (LM-stat)	ADF (t-stat)	KPSS (LM-stat)	ADF (t-stat)	KPSS (LM-stat)
Argentina	-35.448	0.157	-8.057	0.287	-43.862	0.061
Brazil	-27.249	0.159	-20.561	0.157	-46.885	0.117
Chile	-32.725	0.173	-6.424	0.198	-10.665	0.132
U.S.	-10.448	0.187	-23.158	0.119	-29.055	0.108
Mexico	-35.176	0.133	-13.717	0.133	-28.245	0.294
Peru	-23.182	0.216	-3.819	0.453	-21.510	0.155

Note. Appropriate lag selections in the ADF tests are determined by Akaike's information criteria. To calculate the bandwidth for the KPSS test, the Andrew Bandwidth procedure was used. Critical values at the 5% level for the pre-crisis period are as follows: ADF 5%, t-calc. = -2.863. 5% KPSS, t-calc. = 0.463. Critical values at the 5% level for the crisis period are as follows: ADF 5%, t-calc. = -2.869. 5% KPSS, t-calc. = 0.463. Critical values at the 5% level for the post-crisis period are as follows: ADF 5%, t-calc. = -2.862. 5% KPSS, t-calc. = 0.463
Source: elaborated by the authors (2020).

In order to understand how the Latin American markets behave with each other and in relation to the U.S. market, the analyzes of each of the periods described in section 3 are described below.

4.1 Pre-crisis period

Initially, the number of lags of the variables to be included in the model was determined. Most of the information criteria (FPE, AIC, HQIC and SBIC) indicated only one lag (Appendix A). The exogeneity test of variables (Appendix B) indicated that the variable with weak endogeneity was the Argentine market and the Peru market with strong endogeneity. Thus, the ordering used in the Cholesky decomposition was as follows: Argentina ($\chi2$ = 13,411), Mexico ($\chi2$ = 18,864), Brazil ($\chi2$ = 23,904), Chile ($\chi2$ = 25,778), USA ($\chi2$ = 35,441) and Peru ($\chi2$ = 41,015).

After adjusting the final VAR(1) model, obeying the order of exogeneity of the variables, a shock of one standard deviation was transmitted to the other variables using the lag structure of the VAR(1) model (Appendix C) in different intervals of time. Cholesky decomposition was used to perform the impulse response. After 2 periods, the variables tended to stabilize, although the external shock showed positive or negative oscillations in the initial period.

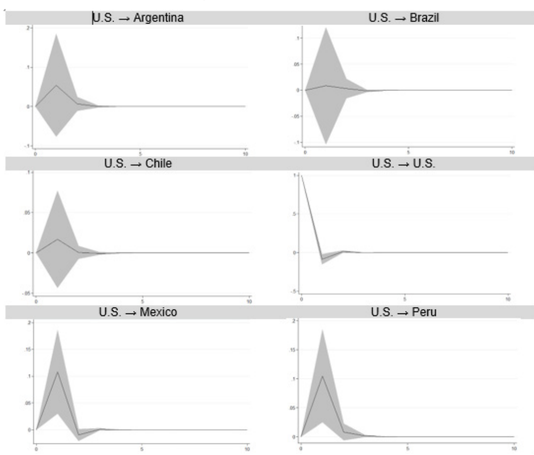

Figure 1. Impulse response of variables using VAR(1) model.
Note. The gray border in each figure represents the 95% confidence interval. In each figure, the "log-returns" are on the vertical and the "horizon" is on the horizontal axis.

After verifying the analysis of the impulse response functions, it is worth verifying the relative participation of each of the variables by decomposing the variance of the forecast errors. Table 2 shows the influence of each market in explaining the variance of the others, measured on the first, fifth and tenth day after an unexpected shock. In the pre-financial crisis period, most of the projected deviations in the market variance are explained by innovations (impacts) of the markets themselves. The American market did not explain in relevant magnitude the variance of any of the other markets. These results are consistent with previous research. Pimenta Jr (2004) and Moterri and Mendes (2005) found evidence of the non-existence of the contagion effect, andwhen it exists, only a portion of the observed interdependencies between Latin American markets results from the influence of the U.S. This is also true for Chile and Peru.

Table 2. Variance Decomposition Percentage Estimates using the VAR(1) model.

Time	Standard Error	Argentina	Mexico	Brazil	Chile	U.S.	Peru
Variance decomposition for Argentina							
1	0.020	100	0	0	0	0	0
5	0.045	99.859	0.003	0.050	0.019	0.067	0.000
10	0.062	99.394	0.013	0.217	0.089	0.284	0.001
Variance decomposition for Mexico							
1	0.012	6.310	93.689	0	0	0	0
5	0.027	7.286	92.620	0.002	0.000	0.082	0.007
10	0.038	8.520	91.103	0.008	0.004	0.328	0.034
Variance decomposition for Brazil							
1	0.017	7.285	21.726	70.987	0	0	0
5	0.038	8.591	22.069	69.300	0.010	0.026	0.002
10	0.052	10.300	22.366	67.166	0.049	0.106	0.010
Variance decomposition for Chile							
1	0.009	4.791	14.745	6.988	73.475	0	0
5	0.020	5.643	14.445	6.197	73.694	0.008	0.012
10	0.029	6.752	14.044	5.356	73.762	0.029	0.055
Variance decomposition for U.S.							
1	0.010	4.352	24.077	7.691	1.991	61.887	0
5	0.022	4.537	24.565	7.911	2.324	60.660	0
10	0.030	4.791	25.112	8.142	2.770	59.183	0
Variance decomposition for Peru							
1	0.012	3.259	4.333	2.257	1.063	0.025	89.060
5	0.028	4.044	4.760	1.774	0.830	0.008	88.582
10	0.040	5.095	5.294	1.321	0.603	0.013	87.671

Note. Order of Cholesky: Argentina, Mexico, Brazil, Chile, U.S., Peru.
Source: elaborated by the authors (2020).

The behavior of the Mexican market has the power to explain the variance of the other markets, the biggest effect being on the U.S. market, around 24%. This result may be associated with greater economic integration between Mexico and the U.S. in the period before the financial crisis (Pimenta Jr, 2004). Other factors that may explain this relationship may include, but not be limited to, commercial relationships and geographic proximity between these countries. The markets of Argentina and Brazil also exert influence over the others, in all cases less than 10%.

The general impression is that in the pre-global financial crisis period, Latin American markets were not affected by the U.S. market, but by the region's own markets. This means that the fall of the Nasdaq in 2000 did not trigger a contagion effect on the markets of Latin America, although the crisis in Brazil in 1999 and the Argentine crisis in 2001 may have increased the levels of interdependence between countries in that region. The relationships existing between the markets in the pre-financial crisis period are favorable for the international portfolio diversification, since the low levels of interdependencies are adequate to minimize investors' exposure to risk.

4.2 Crisis Period

In the selection of lags (Appendix D), two information criteria (HQIC and SBIC) indicated the VAR(1) model, two criteria (FPE and AIC) the VAR(3) model, and one criterion (LR) the VAR (5) model. In view of this divergence, the VAR(3) model was defined, since the FPE and AIC criteria try to define more accurately the number of lags compared to the other information criteria (Thornton & Batten, 1985; Soydemir, 1997). The exogeneity test of the variables (Appendix E) indicated the following order for the Cholesky decomposition : Mexico (X^2 = 5.550), U.S. (X^2 = 8.082), Brazil (X^2 = 14.421), Argentina (X^2 = 23.308), Chile (X^2 = 29.937), Peru (X^2 = 45.556). A shock of one standard deviation was transmitted to the other variables using the lag structure of the VAR(3) model (Appendix F) at different time intervals. Cholesky decomposition was used to perform the impulse response. After 8 periods, the variables tend to stabilize, although the external shock has shown positive and negative oscillations in the initial period.

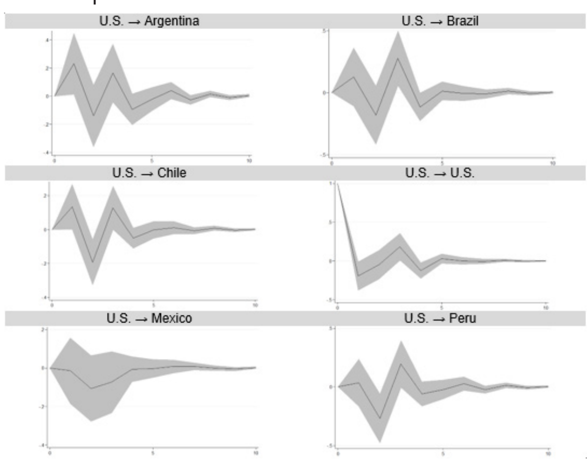

Figure 2. Impulse response of variables using VAR(3) model.
Note. The gray border in each figure represents the 95% confidence interval. In each figure, the "log-returns" are on the vertical and the "horizon" is on the horizontal axis.

By observing the decomposition of variances, it is possible to verify that during the financial crisis the U.S. market had a strong influence in explaining the projected deviations of variance in most Latin American markets. About 65% of the explanation of the variance of the Brazilian market on the first day is due to innovations (impacts) in the U.S. market, decreasing to about 62% on the tenth day. In Argentina, this number is around 48% on the first day and 45% until the tenth, in Chile it is around 41% during the entire period, and in Peru around 29%. This means that the U.S. played a role as a financial contagion vector for Latin America during the crisis.

A possible explanation for this result is presented by Marçal et al. (2011) and Cardona et al. (2017), which emphasize the strong commercial and financial ties between the U.S. and Latin America, in addition to the weak economic fundamentals of Latin countries that were also undergoing a phase of trade liberalization. The uniformity of response from countries in this region confirms that economies with similarities or more intense relationships, such as economic blocks, receive a greater and homogeneous impact from these events (Oliveira, et al. 2019).

The strong impacts from the U.S. to Brazil and Argentina corroborate Davidson (2020) who observed a contagion spreading abruptly from the U.S. to Brazil and Argentina during the financial crisis. As the return of the American market affects the Latin American stock exchanges, there is a reduction in the advantage of these markets as an alternative for portfolio diversification, as it would be desirable that the levels of interdependence between the markets be low to dilute the risk.

During the crisis, the Brazilian market also significantly influenced some markets. The biggest effect is on Peru (about 15%), followed by Argentina (about 14%), and Chile (about 10%). In the case of Mexico, the numbers revealed that most of the projected deviations from market variance are explained by innovations (impacts) in the market itself. They also reveal that their fluctuations do not explain a significant portion of the variance of other markets. Mexico's distancing from other markets may be associated with measures by the Mexican government, which argued vigorously that its economy was sufficiently isolated from the U.S. to go through the crisis without a significant recession (Dooley & Hutchison, 2009).

Table 3. Variance Decomposition Percentage Estimates using the VAR(3) model.

Time	Standard Error	Mexico	U.S.	Brazil	Argentina	Chile	Peru
Variance decomposition for Mexico							
1	0.021	100	0	0	0	0	0
5	0.022	96.279	0.746	0.400	1.429	0.409	0.735
10	0.022	96.024	0.815	0.485	1.488	0.413	0.773
Variance decomposition for U.S.							
1	0.023	0.008	99.991	0	0	0	0
5	0.024	1.492	96.448	1.031	0.495	0.163	0.369
10	0.024	1.494	96.315	1.039	0.603	0.165	0.382
Variance decomposition for Brazil							
1	0.030	0.389	65.986	33.623	0	0	0
5	0.031	1.427	62.586	33.734	1.334	0.844	0.072
10	0.031	1.433	62.450	33.676	1.502	0.847	0.088
Variance decomposition for Argentina							
1	0.027	0.057	48.292	14.243	37.406	0	0
5	0.029	1.131	46.056	14.542	35.714	1.807	0.748
10	0.029	1.166	45.938	14.648	35.654	1.822	0.770
Variance decomposition for Chile							
1	0.017	0.514	42.752	10.202	0.715	45.814	0
5	0.018	4.247	41.100	10.629	2.122	41.756	0.144
10	0.018	4.238	40.985	10.655	2.319	41.632	0.169
Variance decomposition for Peru							
1	0.025	0.005	28.581	15.325	1.989	3.601	50.496
5	0.028	1.374	29.669	15.666	4.379	5.149	43.760
10	0.028	1.438	29.629	15.760	4.419	5.147	43.604

Note. Order of Cholesky: Mexico, U.S., Brazil, Argentina, Chile, Peru.
Source: elaborated by the authors (2020).

4.3 Post-Crisis Period

In the last analysis scenario, most of the information criteria (FPE, AIC, HQIC and SBIC) determined the inclusion of a lag in the model (Appendix G). The exogeneity test of the variables (Appendix H) indicated the following order for the Cholesky decomposition : Brazil (X^2 = 5.686), U.S. (X^2 = 6.406), Argentina (X^2 = 7.538), Mexico (X^2 = 8.264), Chile (X^2 = 27.733) and Peru (X^2 = 29,009). A shock of one standard deviation was transmitted to the other variables using the lag structure of the VAR (1) model (Appendix I) at different time intervals. Cholesky decomposition was used to perform the impulse response. After 2 periods, the variables tended to stabilize, although the external shock showed positive or negative oscillations in the initial period. This behavior is similar to what happened in the pre-crisis period.

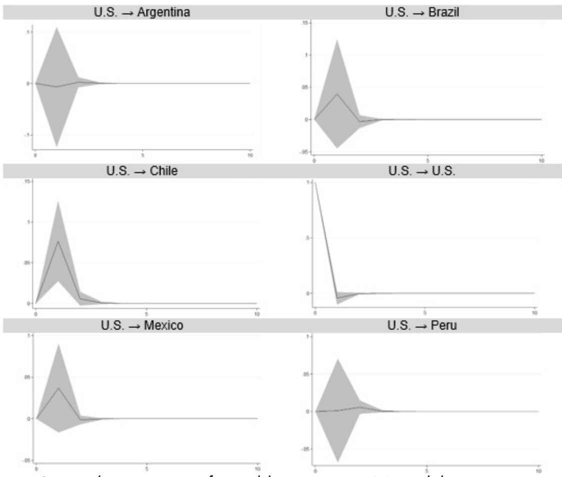

Figure 3. Impulse response of variables using VAR(1) model.

Note. The gray border in each figure represents the 95% confidence interval. In each figure, the "log-returns" are on the vertical and the "horizon" is on the horizontal axis.

From the variance decomposition, it is possible to observe that in the post-financial crisis period most of the projected deviations from the variance of the Latin American markets are again explained by innovations (impacts) of the markets themselves. The American market influences others, but in all cases by less than 10%. This result suggests that after the global financial crisis, the American market continued to exert influence on Latin American stock markets, although its percentage of explanation has significantly reduced.

Table 4. Variance Decomposition Percentage Estimates using the VAR(1) model.

Time	Standard Error	Brazil	U.S.	Argentina	Mexico	Chile	Peru
Variance decomposition for Brazil							
1	0.015	100	0	0	0	0	0
5	0.015	99.870	0.067	0	0.019	0.002	0.040
10	0.015	99.870	0.067	0	0.019	0.002	0.040
Variance decomposition for U.S.							
1	0.009	31.305	68.694	0	0	0	0
5	0.010	31.219	68.630	0.014	0.021	0.110	0.003
10	0.010	31.219	68.630	0.014	0.021	0.110	0.003
Variance decomposition for Argentina							
1	0.020	27.119	6.500	66.380	0	0	0
5	0.020	27.168	6.501	66.301	0.001	0.016	0.011
10	0.020	27.168	6.501	66.301	0.001	0.016	0.011
Variance decomposition for Mexico							
1	0.009	0.245	0.338	0.204	99.210	0	0
5	0.009	0.327	0.479	0.203	98.870	0.031	0.088
10	0.009	0.327	0.479	0.203	98.870	0.031	0.088
Variance decomposition for Chile							
1	0.008	23.265	5.689	0.451	0.039	70.554	0
5	0.008	24.667	6.343	0.451	0.038	68.491	0.007
10	0.008	24.667	6.343	0.451	0.038	68.491	0.007
Variance decomposition for Peru							
1	0.012	16.505	6.738	0.471	0.052	1.395	74.836
5	0.012	17.417	6.702	0.514	0.228	1.422	73.714
10	0.012	17.417	6.702	0.514	0.228	1.422	73.714

Note. Order of Cholesky: Brazil, U.S., Argentina, Mexico, Chile, Peru.
Source: elaborated by the authors (2020).

The behavior of the Brazilian market has the power to explain variance in most other markets: U.S. (31%), Argentina (27%), Chile (24%) and Peru (17%). The markets of Argentina, Chile, Mexico and Peru do not explain a significant portion of the variance of the other markets. The general impression is that after the financial crisis, the countries of this region maintained interdependence bondwith the American market. The Brazilian market significantly increased its influence on other markets, including the U.S., corroborating the premise that developed markets tend to be influenced by emerging markets (Samarakoon, 2011). The increase in financial integration in Latin America may be related to several factors such as the increase in portfolio flows to the region, the growing convergence in market structures and the reduction of financial barriers (IMF, 2016). In other words, if an investor wanted to carry out a portfolio diversification with shares that belong to these indices, he would find some difficulty because a portion of interdependencies among most markets continued to exist.

5 Concluding remarks

This article verified the existence and magnitude of the contagion effect and the interdependencies between Latin American and U.S. markets. It is observed that in the three sample subperiods (pre-crisis, crisis and post-crisis), vector models were adjusted with different lags, VAR(1), VAR(3) and VAR(1), respectively. Showing that in the crisis period the endogenous variables affect the system of simultaneous equations for up to three lag periods and in the other subsamples for only one period.

The analysis of impulse response functions and variance decompositions confirm that in the pre-financial crisis period the levels of interdependence between the Latin American and U.S. markets are insignificant, this complements and updates the evidence from previous studies in the Pimenta Jr region. (2004) and Moretti and Mendes (2005). However, during the crisis period, the results revealed that the U.S. had a power to explain the variance of most Latin American markets, with emphasis on the Brazilian and Argentinian markets, clearly showing a contagion effect. Unlike the evidence presented by Davidson (2020) who documented an abrupt contagion from the U.S. to Brazil and Argentina, these results indicate that this contagion also spread to Chile and Peru in a homogeneous way and in high magnitude.

As financial markets are increasingly integrated due to a context of digitization and ease in international capital flows, investors are diversifying their investment portfolio internationally, seeking uncorrelated assets to minimize their exposure to risk. As markets in this region had low levels of interdependence with each other and with the U.S. in the pre-crisis period, investors may have diversified their investments in Latin American markets.

As a result of this internationalization of investments and economic factors presented by Marçal et al. (2011) and Cardona et al. (2017) is that, in times of turmoil in an economy, markets in other countries are also affected, as occurred in the 2008 crisis. The results also indicated that, after the crisis, the ties between the markets in that region and the American market remained in place, but to a lesser extent. They also indicated an increase in the interdependence of other markets on Brazil, including the U.S.

In theoretical terms, these results expand the literature and present new evidence on the relationship between the markets of Latin America and the U.S. Specifically, the relations between the U.S. and the Chile and Peru markets during the crisis, as well as the post-crisis relations, were not fully elucidated by the previous literature. Considering the strong impact of the financial crisis, markets in this region may still be sensitive to international shocks, so investors should consider periods of financial crisis as a sign of caution in the composition or alteration of their investment portfolio. This fact reinforces the need for regulations and possible political-economic intervention strategies to minimize the exposure of emerging markets to the risk of contagion. This would be useful both for the development of these markets and for attracting international investors. The results also indicate that the possibility of future regional contagion should not be excluded due to the increase in the interdependencies between these markets.

Although the results obtained are theoretically and practically oriented, the scope of this study is limited to the markets analyzed and the time frame considered. As the objective of this research was to understand the macro relations between these capital markets, the role of other crises such as the political crisis that occurred in Brazil (2013 and 2016) were not considered as they were beyond the scope of the work. Future research may consider these crises. This would be useful even for a better understanding of the post-crisis interdependencies found in this research. In addition, it would be promising to verify the impact of the crisis on other financial market assets. Firm-level studies, and the inclusion of behavioral variables such as investor sentiment measures, can also provide new insights into market dynamics in times of crisis.

References

Ahmed, A. D., & Hou, R. (2018). China–Africa financial markets linkages: Volatility and interdependence. *Journal of Policy Modeling*, 40(6), p. 1140-1164. doi:10.1016/j.jpolmod.2018.05.002

Ahmed, A. D., & Huo, R. (2019). Impacts of China's Crash on Asia-Pacific Financial Integration: Volatility Interdependence, Information Transmission and Market Co-movement. *Economic Modelling*, 79, p. 28-46. doi:10.1016/j.econmod.2018.09.029

Aktan, B., Mandaci, P. E., Kopurlu, B. S., & Ensener, B. (2009). Behaviour of emerging stock markets in the global financial meltdown: Evidence from bric-a. *African Journal of Business Management*, 3(7), p. 396-404. doi:10.5897/AJBM09.121

An, L., & Brown, D. (2010). Equity Market Integration between the US and BRIC Countries: Evidence from Unit Root and Cointegration Test. *Research Journal of Internatıonal Studıes*, 16, p. 15-24.

Bergmann, D. R., Securato, J. R., Savoia, J. R., & Contani, E. A. (2015). U.S. subprime financial crisis contagion on BRIC and European Union stock markets. *Revista de Administração (São Paulo)*, 50(2), p. 229-240. doi:10.5700/rausp1196

Borges, W. C., Pimenta Júnior, T., Ambrozini, M. A., & Rodrigues, L. B. S. (2018). O Impacto da Crise Financeira Internacional de 2008 sobre a Estrutura de Capital das Empresas de Países Desenvolvidos e Emergentes. *Revista Contemporânea de Contabilidade*, 15(34), p. 58-75. doi: 10.5007/2175-8069.2018v15n34p58

Chuliá, H., Guillén, M., & Uribe, J. M. (2017). Spillovers from the United States to Latin American and G7 stock markets: A VAR quantile analysis. *Emerging Markets Review*, 31, p. 32-46. doi:10.1016/j.ememar.2017.01.001

Davidson, S. N. (2020). Interdependence or contagion: A model switching approach with a focus on Latin America. *Economic Modelling*, 85, p. 166-197. doi:10.1016/j.econmod.2019.05.015

Dickey, D., & Fuller, W. (1981). Likelihood ratio statistics for autoregressive time series with a unit root. *Econometrica*, 49(4), p. 1057-1072. doi: 10.2307/1912517

Farias, H. P., & Sáfadi, T. (2010). Causalidade entre as principais bolsas de valores do mundo. *Revista de Administração Mackenzie*, 11(2), p. 96-122. doi:10.1590/S1678-69712010000200005

Filleti, J., Hotta, L., & Zevallos, M. (2008). Analysis of contagion in emerging markets. Journal of Data Science, 6, p. 601-626.

Forbes, K., & Rigobon , R. (2001). Measuring contagion: conceptual and empirical issues. *International Financial Contagion*. 1, p. 43-66. doi: 10.1007/978-1-4757-3314-33

Fortunato, G., Martins, N., & Bastian-Pinto, C. L. (2020). Global Economic Factors and the Latin American Stock Markets. *Latin American Business Review* (Binghamton, N.Y.), 21(1), p. 61-91. doi:10.1080/10978526.2019.1665467

IMF. (2016). Financial Integration in Latin America. Fonte: Financial Integration in Latin America: www.imf.org/external/np/pp/eng/2016/030416.pdf

King, M., & Wadhwani, S. (1990). Transmission of volatility between stock markets. *Review of Financial Studies*, 3(1), p. 5-33.

Kwiatkowski, D., Phillips, P., Schmidt, P., & Shin, Y. (1992). Testing the null of stationarity against the alternative of a unit root: How sure are we that economic time series have a unitroot? *Journal of Econometrics*, p. 159-178.

Lee, H. (2011). Contagion in international stock markets during the sub prime mortgage crisis. *International Journal of Economics and Financial Issues*, 2(1), p. 41-53.

Marçal, E. F., Pereira, P. L., Martin, D. M., & Nakamura, W. T. (2011). Evaluation of contagion or interdependence in the financial crises of Asia and Latin America, considering the macroeconomic fundamentals. *Applied Economics*, 43, p. 2365–2379. doi:10.1080/00036840903194204

Markowitz, H. (1952). Portfolio selection. *The Journal of Finance*, 7(1), p. 77-91. doi: 10.1111/j.1540-6261.1952.tb01525.x

Moretti, A. R., & Mendes, B. V. (2005). Medindo a influência do mercado dos EUA sobre as interdependências observadas na América Latina. *Revista Brasileira de Finanças*, 3(1), p. 123-137. doi: 10.12660 / rbfin.v3n1.2005.1147

Nashier, T. (2015). Financial integration between BRICS and developed stock markets. *International Journal of Business and Management Invention*, 4(1), p. 65-71.

Oliveira, F. F., Albuquerque, A. A., & Carvalho, F. L. (2019). Estudo das inter-relações entre os mercados acionários do BRICS e dos Estados Unidos. *Revista Contabilidade Vista & Revista*, 30(2), p. 01-21. doi:10.22561/cvr.v30i2.4717

Pimenta Jr, T. (2004). Uma mensuração do fenômeno da interdependência entre os principais mercados acionários da América Latina e a Nasdaq. *Revista de Administração* (São Paulo), 39(2), p. 177-185.

Pimenta Jr, T., & Famá, R. (2002). Interdependence Between the Major Capital Markets of the Emerging Countries of Latin America and Southeast Asia. *Latin American Business Review*, 3(3), p. 1-25. doi:10.1300/J140v03n03_01

Ribeiro, A. L., & Hotta, L. K. (2013). An analysis of contagion among Asian countries using the canonical model of contagion. *International Review of Financial Analysis*, 29, p. 62-69. doi:10.1016/j.irfa.2013.03.014

Samarakoon, L. P. (2011). Stock market interdependence, contagion, and the U.S. financial crisis: the case of emerging and frontier markets. *Journal of International Financial Markets, Institution and Money*, 21(5), p. 724-742. doi:10.1016/j.intfin.2011.05.001

Santos, C. M., Gaio, L. E.; Pimenta Junior, T., & Cicconi, E.G. (2019). Interdependence and contagion in the period of crisis. *International Journal of Emerging Markets*, 14(5), p. 1013-1031. doi: 10.1108/IJOEM-05-2018-0216

Senna, V., & Souza, A. M. (2016). Assessment of the relationship of government spending on social assistance programs with Brazilian macroeconomic variables. *Physica A*, 462, p. 21-30. doi:10.1016/j.physa.2016.05.022.

Sims, C. A. (1980). Macroeconomics and reality. *Econometrica*, 48(1), p. 1-48. doi: 10.2307/1912017

Soydemir, G. (1997). *The linkages between national stock markets: evidence from emerging markets*. Thesis (Doctoral) – Faculty of the Claremont Graduate School, Claremont,.

Vartanian, P. F. (2012). Impactos do índice Dow Jones, commodities e câmbio sobre o Ibovespa: uma análise do efeito contágio. *Revista de Administração Contemporânea*, 16(4), p. 608-627. doi:10.1590/S1415-65552012000400007.

Wang, G.-J., Xie, C., Lin, M., & Stanley, E. (2017). Stock market contagion during the global financial crisis: A multiscale approach. *Finance Research Letters*, 22, p. 163-168. doi:10.1016/j.frl.2016.12.025

Zorgati, I., Lakhal, F., & Zaabi, E. (2019). Financial contagion in the subprime crisis context: A copula approach., 47, p. 269-282. doi:10.1016/j.najef.2018.11.014

Appendix A: Selection of VAR model lag number (pre-crisis period).

Lag	Log likeliho-od	LR	FPE	AIC	HQIC	SBIC
1	24959.1	NA	8.1e-24*	-361.467*	-360.956*	-360.101*
2	24987.3	56.409	8.2e-24	-361.354	-360.332	-358.623
3	25002.6	30.493	8.4e-24	-361.053	-359.520	-356.957
4	25028.9	52.729*	8.5e-24	-360.913	-358.873	-355.452
5	25047.2	36.608	8.8e-24	-360.656	-358.103	-353.831

Note. LR is the modified sequential LR statistical test (each test at the 5% level), FPE is the Final Prediction Error, AIC is the Akaike information criterion, HQIC is the Hannan-Quinn criterion, and SBIC is Schwarz's Bayesian criterion.
Source: elaborated by the authors (2020).

Appendix B: Variable Exogeneity Test – VAR Granger Causality/Block Exogeneity Wald Tests (pre-crisis period).

	(1) Argentina		(2) Brasil		(3) Chile		(4) México		(5) Peru		(6) EUA	
	χ2	Prob.	χ2	Prob.	χ2	Prob.	χ2	Prob.	χ2	Prob.	χ2	Prob.
(1)			10.914	0.004	6.626	0.036	5.205	0.074	6.041	0.048	1.473	0.478
(2)	5.043	0.080			2.080	0.353	1.103	0.575	1.703	0.426	4.846	0.088
(3)	4.787	0.091	1.307	0.520			0.182	0.912	3.420	0.180	4.536	0.103
(4)	3.290	0.193	3.634	0.162	3.781	0.151			9.113	0.010	6.888	0.031
(5)	0.534	0.765	1.782	0.410	10.835	0.004	3.260	0.195			2.869	0.238
(6)	5.164	0.075	0.848	0.645	0.330	0.847	8.674	0.195	6.541	0.038		
Total	13.411	0.201	23.904	0.007	25.778	0.004	18.864	0.042	41.015	0.000	35.441	0.000

All variables were calculated as the logarithm return of each country's main market index.
Source: elaborated by the authors (2020).

Appendix C: VAR (1) model represented in order from exogenous to endogenous (pre-crisis period).

	Argentina	Mexico	Brazil	Chile	U.S.	Peru
ARGENTINA(-1)	0.042	0.003	–0.037	-0.003	-0.016	0.021
	[0.028]	[0.167]	[0.024]	[0.012]	[0.014]	[0.017]
	(0.134)	(0.849)	(0.126)	(0.813)	(0.251)	(0.206)
MEXICO(-1)	–0.079	0.020	0.094	0.050	0.069	0.070
	[0.057]	[0.034]	[0.049]	[0.026]	[0.029]	[0.035]
	(0.164)	(0.551)	(0.056)	(0.056)	(0.017)	(0.045)
BRASIL(-1)	-0.039	–0.014	0.005	–0.006	–0.044	0.019
	[0.040]	[0.024]	[0.034]	[0.186]	[0.020]	[0.024]
	(0.329)	(0.560)	(0.879)	(0.735)	(0.031)	(0.425)
CHILE(-1)	–0.030	0.011	-0.045	0.113	0.062	-0.054
	[0.690]	[0.041]	[0.059]	[0.031]	[0.035]	[0.042]
	(0.660)	(0.783)	(0.445)	(0.000)	(0.072)	(0.199)
U.S.(-1)	0.053	0.108	0.008	0.167	-0.088	0.104
	[0.066]	[0.039]	[0.057]	[0.306]	[0.033]	[0.040]
	(0.419)	(0.006)	(0.884)	(0.584)	(0.009)	(0.010)
PERU(-1)	0.121	–0.025	–0.032	–0.048	–0.039	0.089
	[0.045]	[0.027]	[0.039]	[0.041]	[0.023]	[0.027]
	(0.790)	(0.343)	(0.410)	(0.020)	(0.087)	(0.001)

Note. All variables were calculated as the logarithmic return of the main country cover index. Order of Cholesky: Argentina, Mexico, Brazil, Chile, U.S., Peru. Coefficient in the first line, p-value in parentheses and standard error in square brackets.
Source: elaborated by the authors (2020).

Appendix D: Selection of VAR Model Lag Number (Crisis Period).

Lag	Log likeliho-od	LR	FPE	AIC	HQIC	SBIC
1	5455.14	NA	2.0e-21	-476.439	-474.873*	-472.504*
2	5491.74	73.187	2.0e-21	-476.473	-473.341	-468.603
3	5528.28	73.081	2.0e-21*	-476.503*	-471.806	-464.698
4	5554.99	53.431	2.1e-21	-475.978	-469.716	-460.239
5	5591.90	73.821*	2.1e-21	-476.032	-468.202	-456.356

Note. LR is the modified sequential LR statistical test (each test at the 5% level), FPE is the Final Prediction Error, AIC is the Akaike information criterion, HQIC is the Hannan-Quinn criterion, and SBIC is Schwarz's Bayesian criterion.
Source: elaborated by the authors (2020).

Appendix E: Variable Exogeneity Test – VAR Granger Causality/Block Exogeneity Wald Tests (Crisis Period).

	(1) Argentina		(2) Brazil		(3) Chile		(4) Mexico		(5) Peru		(6) U.S.	
	χ2	Prob.	χ2	Prob.	χ2	Prob.	χ2	Prob.	χ2	Prob.	χ2	Prob.
(1)			4.218	0.121	2.811	0.245	0.250	0.882	10.270	0.005	1.290	0.524
(2)	0.565	0.753			0.529	0.767	1.101	0.576	3.298	0.192	0.425	0.808
(3)	5.317	0.070	3.052	0.217			0.485	0.784	7.980	0.018	0.434	0.804
(4)	2.693	0.260	1.488	0.475	7.102	0.028			2.616	0.270	3.071	0.215
(5)	2.814	0.244	0.183	0.912	0.779	0.677	1.981	0.371			1.196	0.549
(6)	8.343	0.015	3.691	0.157	16.040	0.003	0.518	0.771	11.820	0.002		
Total	23.308	0.009	14.421	0.154	29.937	0.000	5.550	0.851	45.556	0.000	8.082	0.620

All variables were calculated as the logarithm return of each country's main market index.
Source: elaborated by the authors (2020).

Appendix F: VAR (3) model represented in order from exogenous to endogenous (Crisis Period).

	Mexico	U.S.	Brazil	Argentina	Chile	Peru
MEXICO(-1)	0.104	0.031	–0.019	0.023	0.002	–0.015
	[0.054]	[0.058]	[0.075]	[0.069]	[0.042]	[0.064]
	(0.057)	(0.596)	(0.796)	(0.744)	(0.959)	(0.812)
MEXICO(-2)	–0.090	0.098	0.095	0.119	0.119	0.120
	[0.054]	[0.058]	[0.075]	[0.069]	[0.042]	[0.064]
	(0.099)	(0.092)	(0.204)	(0.085)	(0.005)	(0.063)
MEXICO(-3)	–0.030	–0.062	–0.067	0.006	–0.101	–0.073
	[0.055]	[0.059]	[0.075]	[0.069]	[0.043]	[0.064]
	(0.579)	(0.289)	(0.371)	(0.931)	(0.018)	(0.253)
U.S.(-1)	–0.013	–0.194	0.128	0.231	0.135	0.035
	[0.089]	[0.096]	[0.124]	[0.114]	[0.070]	[0.106]
	(0.877)	(0.044)	(0.301)	(0.044)	(0.054)	(0.740)
U.S.(-2)	–0.095	–0.099	–0.130	–0.053	–0.170	–0.288
	[0.094]	[0.101]	[0.130]	[0.120]	[0.074]	[0.111]
	(0.314)	(0.326)	(0.315)	(0.657)	(0.022)	(0.010)
U.S.(-3)	–0.122	0.146	0.167	0.058	0.066	0.059
	[0.089]	[0.096]	[0.124]	[0.114]	[0.070]	[0.106]
	(0.173)	(0.129)	(0.176)	(0.614)	(0.344)	(0.579)
BRAZIL(-1)	0.043	–0.066	–0.102	–0.031	–0.039	0.185
	[0.085]	[0.091]	[0.117]	[0.108]	[0.066]	[0.100]
	(0.610)	(0.463)	(0.381)	(0.772)	(0.552)	(0.065)
BRAZIL(-2)	0.093	–0.002	–0.098	–0.006	0.015	0.020
	[0.085]	[0.090]	[0.116]	[0.107]	[0.066]	[0.100]

	(0.275)	(0.977)	(0.396)	(0.952)	(0.818)	(0.842)
BRAZIL(-3)	0.101	–0.096	–0.167	–0.006	–0.029	0.003
	[0.084]	[0.089]	[0.115]	[0.107]	[0.065]	[0.098]
	(0.229)	(0.280)	(0.146)	(0.952)	(0.650)	(0.975)
ARGENTINA(-1)	–0.030	0.079	0.066	0.023	0.012	0.193
	[0.068]	[0.073]	[0.094]	[0.086]	[0.053]	[0.080]
	(0.659)	(0.280)	(0.480)	(0.795)	(0.822)	(0.016)
ARGENTINA(-2)	0.000	0.019	0.163	0.136	0.081	0.170
	[0.068]	[0.073]	[0.094]	[0.087]	[0.053]	[0.081]
	(0.998)	(0.797)	(0.083)	(0.118)	(0.129)	(0.035)
ARGENTINA(-3)	–0.147	–0.062	–0.050	–0.151	–0.061	–0.085
	[0.068]	[0.073]	[0.094]	[0.087]	[0.053]	[0.080]
	(0.031)	(0.391)	(0.589)	(0.081)	(0.248)	(0.287)
CHILE(-1)	–0.066	0.058	–0.202	–0.305	0.053	–0.288
	[0.105]	[0.113]	[0.145]	[0.134]	[0.082]	[0.124]
	(0.53)	(0.607)	(0.164)	(0.023)	(0.517)	(0.021)
CHILE(-2)	0.065	0.034	0.091	0.010	0.099	0.146
	[0.107]	[0.115]	[0.148]	[0.137]	[0.084]	[0.127]
	(0.541)	(0.766)	(0.538)	(0.942)	(0.240)	(0.249)
CHILE(-3)	0.046	0.046	0.067	0.026	0.048	0.203
	[0.103]	[0.111]	[0.143]	[0.131]	[0.081]	[0.122]
	(0.65)	(0.677)	(0.638)	(0.846)	(0.551)	(0.097)
PERU(-1)	–0.044	–0.048	–0.008	–0.055	–0.026	–0.073
	[0.064]	[0.069]	[0.089]	[0.082]	[0.050]	[0.076]
	(0.487)	(0.483)	(0.923)	(0.500)	(0.602)	(0.337)
PERU(-2)	–0.065	0.058	0.045	0.102	0.022	0.152
	[0.062]	[0.067]	[0.086]	[0.080]	[0.049]	[0.074]
	(0.299)	(0.386)	(0.605)	(0.201)	(0.647)	(0.040)
PERU(-3)	0.076	0.019	–0.003	0.089	–0.020	–0.016
	[0.061]	[0.065]	[0.084]	[0.078]	[0.048]	[0.072]
	(0.211)	(0.769)	(0.970)	(0.253)	(0.665)	(0.814)

All variables were calculated as the logarithm return of each country's main market index. Order of Cholesky: Mexico, U.S., Brazil, Argentina, Chile, Peru. Coefficient in the first line, p-value in parentheses and standard error in square brackets.

Source: elaborated by the authors (2020).

Appendix G: Selection of VAR model lags (Post-crisis Period).

Lag	Log likeliho-od	LR	FPE	AIC	HQIC	SBIC
1	40142.5	NA	2.5e-24*	-373.257*	-372.911*	-372.307*
2	40178.3	71.64	2.5e-24	-373.256	-372.562	-371.355
3	40208.5	60.4*	2.5e-24	-373.202	-372.159	-370.351
4	40230.7	44.33	2.5e-24	-373.073	-371.682	-369.272
5	40252.5	43.69	2.6e-24	-372.941	-371.203	-368.190

Note. LR is the modified sequential LR statistical test (each test at the 5% level), FPE is the Final Prediction Error, AIC is the Akaike information criterion, HQIC is the Hannan-Quinn criterion, and SBIC is Schwarz's Bayesian criterion.

Source: elaborated by the authors (2020).

Appendix H: Variable Exogeneity Test – VAR Granger Causality/Block Exogeneity Wald Tests (Post-crisis Period).

	(1) Argentina		(2) Brazil		(3) Chile		(4) Mexico		(5) Peru		(6) U.S.	
	$\chi 2$	Prob.	$\chi 2$	Prob.	$\chi 2$	Prob.	$\chi 2$	Prob.	$\chi 2$	Prob.	$\chi 2$	Prob.
(1)			0.243	0.885	0.881	0.643	0.174	0.916	4.212	0.121	0.392	0.121
(2)	0.759	0.684			3.710	0.156	0.126	0.938	6.205	0.044	1.325	0.515
(3)	0.419	0.810	0.038	0.981			0.728	0.694	2.852	0.240	4.258	0.118
(4)	0.080	0.960	1.764	0.413	0.220	0.895			4.401	0.110	0.475	0.788
(5)	5.293	0.070	1.935	0.379	4.252	0.119	2.288	0.318			0.324	0.850
(6)	0.078	0.961	1.162	0.559	7.344	0.025	1.879	0.390	0.132	0.935		
Total	7.538	0.673	5.686	0.840	27.733	0.002	8.264	0.603	29.009	0.001	6.406	0.780

All variables were calculated as the logarithm return of each country's main market index.

Source: elaborated by the authors (2020).

Appendix I: VAR model (1) represented in order from exogenous to endogenous (Post-crisis Period).

	Brazil	U.S.	Argen-tina	Mexico	Chile	Peru
BRASIL(-1)	-0.031	0.015	0.004	0.002	0.033	0.049
	[0.028]	[0.019]	[0.039]	[0.018]	[0.016]	[0.023]
	(0.227)	(0.427)	(0.906)	(0.912)	(0.046)	(0.035)
U.S.(-1)	0.039	-0.042	-0.007	0.036	0.076	0.000
	[0.042]	[0.028]	[0.059]	[0.027]	[0.025]	[0.035]
	(0.356)	(0.133)	(0.906)	(0.176)	(0.002)	(0.979)
ARGENTINA(-1)	-0.001	0.007	0.051	–0.000	0.003	0.010
	[0.019]	[0.012]	[0.026]	[0.012]	[0.011]	[0.015]
	(0.958)	(0.531)	(0.054)	(0.981)	(0.743)	(0.520)
MEXICO(-1)	0.020	0.014	-0.007	0.059	0.001	0.052
	[0.034]	[0.022]	[0.047]	[0.021]	[0.019]	[0.027]
	(0.539)	(0.525)	(0.881)	(0.006)	(0.927)	(0.059)
CHILE(-1)	-0.015	-0.045	0.031	-0.027	0.098	0.024
	[0.043]	[0.028]	[0.059]	[0.027]	[0.025]	[0.035]
	(0.720)	(0.108)	(0.598)	(0.313)	(0.000)	(0.489)
PERU(-1)	0.028	0.005	0.020	0.026	–0.007	0.078
	[0.030]	[0.019]	[0.041]	[0.019]	[0.017]	[0.024]
	(0.350)	(0.790)	(0.620)	(0.167)	(0.672)	(0.001)

All variables were calculated as the logarithm return of each country's main market index. Order of Cholesky: Brazil, U.S., Argentina, Mexico, Chile, Peru. Coefficient in the first line, p-value in parentheses and standard error in square brackets.

Source: elaborated by the authors (2020).