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New evidence on financial integration in Latin America

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Abstract

We revisit the financial interconnectedness in Latin America from 1993 to 2022 using Diebold-Yilmaz's (2012, 2014) approach in the generalized VAR framework. Full-sample and rolling-sample analyses reveal high and fluctuating cross-market linkages over time. Three notable periods of intense integration are identified: the first period coincides with the global financial crisis, the second with the Argentinian great depression, and the third encompasses two significant events, namely the COVID-19 pandemic and the Ukraine-Russia war, with the global financial crisis exerting the most pronounced influence. The Brazilian market is the most integrated among Latin American markets, while the Colombian market is the most segmented. These findings suggest limited diversification benefits during turbulent times and have practical implications for policymakers and international investors.

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1. Introduction

Financial market integration among economies and regions has been a significant focus for researchers and policymakers in the last three decades.[1] This focus is due to market liberalization policies,[2] crises, and disruptions that affect levels of integration. Increased financial connections can provide benefits such as enhanced risk-sharing and portfolio diversification, which leads to economic growth. However, intensified integration may impede the achievement of certain policy objectives, diminish the benefits of diversification, and increase the risk of financial contagion.

Prior to discussing our study's contribution, we provide a concise overview of the existing research on financial integration in Latin America. Indeed, Meric *et al*. (2001) examine the portfolio diversification of US investors in Argentina, Brazil, Chile, and Mexico over the 1984-1995 period, and reveal increasing correlations over time, with no significant benefits for US investors holding diversified Latin American stocks. Chen *et al*. (2002) display interdependencies among stock prices of Argentina, Brazil, Chile, Colombia, Mexico, and Venezuela from 1995 to 2000, and establish that investing in different Latin American markets offers little potential for risk diversification. Johnson and Soenen (2003) reveal a significant degree of contemporaneous correlation between the US market and the equity markets of Argentina, Brazil, Canada, Chile, Colombia, Mexico, Peru, and Venezuela from 1988 to 1999. According to Fujii (2005), there are significant and time-varying cross-market interactions among four Latin American markets (Argentina, Brazil, Chile, and Mexico) from 1990 to 2001, with the causal links tending to strengthen, particularly in periods of major financial crises. Lucey and Zhang (2007) indicate that the equity markets of Argentina, Brazil, Chile, Colombia, Mexico, Peru, and Venezuela do not integrate either within the region or with the US market between 1993 and 2007, suggesting long-term diversification benefits for US and other international investors. Arouri *et al*. (2013) discover dynamic cross-market relationships between the US and Latin American economies (Argentina, Brazil, Chile, and Mexico) from 1988 to 2009, but do not find substantial support for the financial contagion hypothesis. From 1993 to 2016, Coleman *et al*. (2019) identify significant ties between the US and six Latin American markets (Argentina, Brazil, Chile, Mexico, Peru, and Venezuela) but do not emphasize the US preeminent role. Davidson (2020) finds out interdependence between Argentina, Brazil, and Mexico during the currency crises of the 1990s and the 1998–2002 Argentine crisis, contagion from the US to Argentina and Brazil during the global stock market crash, and contagion through existing interdependencies between the US and Mexico.

This literature has key limitations that motivate us to undertake a fresh investigation into the integration of the stock markets in Latin America. Indeed, the current study examines the co-movements in the equity markets of Argentina, Brazil, Chile, Colombia, Mexico, and Peru, with an emphasis on the understudied financial integration between Colombia, Peru, and the other countries in the region. These countries have been selected because they are pursuing regional integration under the guidance of the Latin American Integration Association (LAIA). The purpose of the study is to evaluate how economic cooperation, capital market liberalization, and previous financial crises have impacted stock market integration in the region, with implications for policymakers and international investors.

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[1] Patel *et al*. (2022) conduct a meta-review, identifying research groups and emphasizing the significance of their findings for academicians and policymakers. Readers are also referred to Haddad (2023) for a comprehensive analysis of previous research on financial market integration.

[2] Market-opening policies increase the efficiency of the financial system through eradicating inefficient financial markets, enhancing the financial infrastructure, and enacting reasonable legal and institutional procedures.

The study considers the period from 1993 to 2022, including recent events such as the stock market collapse in 2020 caused by COVID-19 and the Russo-Ukrainian war in 2022. It compares these events to previous crises, such as the 1998-2002 Argentine Great Depression and the 2008-2009 global financial crisis, in order to comprehend their effect on cross-market links.[3] Changes in equity market integration during crises have an effect on portfolio diversification returns, providing investors and authorities with useful information for managing contagion risks and market policies.

The focus of this study is the dynamic character of stock market integration among the countries under consideration. To accomplish this, it employs an innovative approach developed by Diebold and Yilmaz (2012, 2014) that evaluates the interconnectedness of equity markets as a whole and analyzes directional linkages both statically and dynamically using a rolling-window approach over the entire sample period. In contrast to previous research on Latin America using primarily cointegration and correlation-based procedures, Diebold-Yilmaz's approach stands out due to its ability to identify the most influential stock market for predicting and explaining fluctuations in all other stock markets. This enables a thorough analysis of market integration, resulting in distinctive findings and relevant conclusions.

The study concludes by examining the effect of Diebold-Yilmaz's method parameters on the results, which is significant because previous research on the region has not examined the validity of these findings. The objective is to ensure that the study yields credible findings and policy-relevant insights regarding the diversification of stock portfolios in Latin America.

The study's findings are significant and reveal high interconnection among the markets, reducing the benefits of portfolio diversification for international investors. Cross-market linkages fluctuate during major events, with three distinct periods of high integration, pushed primarily by the global financial crisis, supporting the notion of financial contagion. The study also emphasizes the prominent role of the Brazilian market in predicting the dynamics of other markets, as well as the robustness of these findings under various analytic approaches. These insights have implications for investors and policymakers in the real-world setting.

The paper's structure is as follows. Section 2 explains the econometric methodology. Section 3 covers data and discusses empirical findings on market interconnectedness. Section 4 provides a robustness check using alternative specifications. Section 5 concludes with key insights and policy implications.

2. Econometric methodology

A major challenge in measuring financial integration consists in identifying a reliable and accurate metric. Various empirical methodologies are used in the literature to assess regional financial integration, including standard unconditional correlation, PCA-based measure, multi-factor adjusted R-square, Ball-Torous's correlation coefficient adjusted for stochastic interdependence, Forbes-Rigobon's volatility-adjusted correlation, BEKK-GARCH and DCC-GARCH-based correlation coefficients, equi-correlation approach, conditional time-varying beta, CoVaR method, time-varying Copula, Bayesian dynamic latent factor approach, Granger-causality and cointegration approaches, etc. In this context, Billio *et al*. (2017) employ a wide range of metrics to evaluate the financial integration in both developed and emerging markets.

[3] During the study period, further domestic and international events, including the 1994 Mexican economic crisis, the 1997-1999 Asian and Russian financial crises, the 1999 Brazilian currency crisis, the 2001 US recession, the 2000-2002 US dot-com bubble, the 2011-2013 US debt ceiling and budget crisis, the 2014-2017 Brazilian economic crisis, and the 2018 Argentine monetary crisis, influenced the stock markets.

Diebold and Yilmaz (2012, 2014) contend that while the aforementioned measures are indeed intriguing, they assess distinct aspects,[4] and a cohesive framework is still difficult to achieve. In order to tackle this issue, they develop a comprehensive framework that can be easily analysed using econometric methods, even when dealing with a large number of assets. This framework allows for the conceptualization and empirical measurement of connectedness at various levels, ranging from individual pairs to the entire system. It is based on rigorous theoretical foundations and can be easily implemented in real-world scenarios. Moreover, it considers the multiple strengths of different connections and how connectedness changes over time.

To evaluate the potential interdependence among the stock markets, we apply Diebold and Yilmaz's (2012, 2014) approach, which involves the VAR model and the generalized forecast error variance decomposition (GFEVD) method. This approach enables the study of bidirectional spillovers in a generalized VAR framework, eradicating sensitivity issues related to variable ordering in variance decomposition when assessing the influence of one variable on another's variation.

The analysis is based on the following N-return VAR(p) model:[5]

$$X_t = \sum_{i=1}^{p} \Phi_i X_{t-i} + u_t \tag{1}$$

where X_t is a $(N \times 1)$ vector of returns at time t, u_t is a $(N \times 1)$ vector of independently and identically distributed error terms at time t, Φ_i is a $(N \times N)$ matrix of coefficients, and p is the order of the model. The variance decomposition method calculates the fractions of the H-period-ahead error variances in forecasting the variable X_i that are attributable to shocks to the variable X_j for $i, j = 1, 2, \ldots, N$ and $i \neq j$. The analytical expression for the H-step-ahead GFEVD is as follows:

$$\psi_{ij}^{H} = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} \left(e_i' \mathrm{B}_h \Sigma_u e_j\right)^2}{\sum_{h=0}^{H-1} \left(e_i' \mathrm{B}_h \Sigma_u \mathrm{B}_h' e_i\right)}, \qquad for\ H = 1, 2, \ldots \tag{2}$$

where $\sum_{j=1}^{N} \psi_{ij}^{H} \neq 1$, Σ_u is the covariance matrix of the disturbance vector u_t, σ_{jj} is the standard deviation of the disturbance term of the jth equation in the system, e_i is the selection vector where the ith element takes one and the remaining elements take zeros, and B_h is a $(N \times N)$ coefficient matrix that obeys the recursion $\mathrm{B}_h = \Phi_1 \mathrm{B}_{h-1} + \Phi_2 \mathrm{B}_{h-2} + \cdots + \Phi_p \mathrm{B}_{h-p}$ with B_0 an $(N \times N)$ identity matrix and $\mathrm{B}_h = 0$ for $h < 0$. Each entry of the variance decomposition matrix is normalized as follows in order to construct the spillover index:

$$\tilde{\psi}_{ij}^{H} = \frac{\psi_{ij}^{H}}{\sum_{j=1}^{N} \psi_{ij}^{H}}, \quad \text{with } \sum_{j=1}^{N} \tilde{\psi}_{ij}^{H} = 1 \text{ and } \sum_{i,j=1}^{N} \tilde{\psi}_{ij}^{H} = N \tag{3}$$

The total spillover index is calculated as follows:

$$S^{H} = \frac{1}{N} \sum_{i,j=1}^{N} \tilde{\psi}_{ij}^{H}, \qquad for\ i \neq j \tag{4}$$

This index evaluates the interdependence of the entire system by determining the contribution of variance shock spillovers across all variables to the total forecast error variance. In this

[4] Correlation-based methods are not able to accurately evaluate financial integration, meaning that even if two markets are perfectly integrated, their stock returns may not show a perfect correlation (Pukthuanthong and Roll, 2009; and Volosovych, 2011). The Granger-causal and cointegration methods do not yield insights into the extent of financial integration.

[5] The equity index returns are computed as the log difference of two successive stock market prices.

setting, the index spans between zero and one, indicating that the stock markets are either all completely segmented or all completely integrated.

The directional volatility spillovers received by the variable i from all the other variables j (i.e., the amount received by the variable i from all the other variables j) are computed as follows:

$$S_{i\cdot}^{H} = \frac{\sum_{\substack{j=1 \\ j\neq i}}^{N} \tilde{\Psi}_{ij}^{H}}{\sum_{j=1}^{N} \tilde{\Psi}_{ij}^{H}} \tag{5}$$

Similarly, the directional volatility spillovers transmitted by variable i to all other variables j (i.e., the amount that variable i contributes to all other variables j) are given as follows:

$$S_{\cdot i}^{H} = \frac{\sum_{\substack{j=1 \\ j\neq i}}^{N} \tilde{\Psi}_{ji}^{H}}{\sum_{j=1}^{N} \tilde{\Psi}_{ji}^{H}} \tag{6}$$

The net volatility spillover from variable i to all other variables j (the variable i's net contribution to volatility in all other variables j) can be calculated as follows:

$$S_{i}^{H} = S_{\cdot i}^{H} - S_{i\cdot}^{H} \tag{7}$$

The net pairwise volatility spillover between the variables i and j (the difference between the gross variance shocks transmitted from the variable i to the variable j and the gross variance shocks transmitted from the variable j to the variable i) is another factor to be evaluated as follows:

$$S_{ij}^{H} = \frac{\tilde{\Psi}_{ij}^{H}}{\sum_{k=1}^{N} \tilde{\Psi}_{ik}^{H}} - \frac{\tilde{\Psi}_{ji}^{H}}{\sum_{k=1}^{N} \tilde{\Psi}_{jk}^{H}} \tag{8}$$

3. Data, results, and discussion

We examine monthly MSCI indices for six Latin American countries from January 1993 to April 2022: Argentina, Brazil, Chile, Colombia, Mexico, and Peru.[6] This choice of monthly data is in line with prior research on time-varying stock market integration, such as Pukthuanthong and Roll (2009), Yu *et al*. (2010), Volosovych (2011), Coleman *et al*. (2019), and Davidson (2020). Additionally, it helps mitigate common issues associated with high-frequency data, particularly in emerging equity markets, as suggested by Billio *et al*. (2017).

3.1 Full-sample analysis

The connectedness matrix, which reveals spillover indices according to Eqs. (3)-(7), is presented in Table 1.[7] The overall spillover index for the entire sample period is 59.61%, indicating that the six stock markets are highly integrated financially. This suggests that diversification benefits for investors in these markets may be limited. The similar values in the "From others" column, mostly near or above 60%, indicate that each market receives valuable information from the others. The top receivers are Brazil, Chile, and Mexico, with the highest gross directional spillovers to the Brazilian market at 64.71%, followed by the Chilean market at 61.98% and the Mexican market at 61.01%. There are significant differences in contributions

[6] Data are gathered from the MSCI Barra database and denominated in US dollars to preserve cross-market homogeneity and avoid currency risk effects.

[7] According to the Schwarz information criterion, the VAR model has an order of one. We have also examined the sensitivity of the order selection to other criteria, such as the Akaike information criterion and the Hannan-Quinn information criterion, and discovered the same optimal lag length for the VAR system, indicating that the order selection is robust to various criteria. Following Zhang (2017), the time horizon H is set at 10 months, as the elements of the generalized variance decomposition matrix may change for too small values of H or converge rapidly to stable values for a longer time horizon H.

to other markets ("To others" row), with the top three contributors (which are also the top receivers) accounting for over 65% of the spillovers. This implies that Brazil, Chile, and Mexico exert the most influence on the other markets while also being most exposed to disruptions and information spillovers from their counterparts.

The net directional spillover analysis identifies Brazil, Chile, and Mexico as net contributors to the system during the study period, with Brazil leading the pack with a contribution of 10.5%, followed by Chile and Mexico at approximately 5.6% each. In contrast, Argentina, Colombia, and Peru are net receivers, with Colombia having the highest value (-14.54%), followed by Argentina (-6.37%) and Peru (-0.84%). These findings underscore the Brazilian stock market's central role in regional financial integration, due to its market size and influence, while the Colombian market appears to be relatively more segmented in comparison.

Figure 1 illustrates the relationships between stock index returns over the entire study period by depicting 15 arrows connecting various markets, with the arrow moving from market i to market j if market i contributes more than it receives from market j ($i \neq j$). Brazil stands out as the largest net contributor, influencing all five stock markets without receiving any influence in return, making it the most influential market and a useful predictor of the dynamics of other markets. Chile wields significant influence as well. Conversely, as the largest net receiver, Colombia is influenced by all markets but contributes to none. Despite its economic size, Argentina's influence is limited, as it is affected by four markets while contributing to only one. These variations in equity market integration likely stem from differences in market development and various economic, political, legal, and institutional factors.

3.2 Rolling-sample analysis

The full-sample analysis provides insight into the average interconnections between equity markets, but it may overlook fluctuations resulting from various shocks and regional developments. To capture these dynamic patterns, in accordance with Diebold and Yilmaz's methodology, we undertake a 60-month rolling analysis[8] in which we iteratively estimate VAR models using overlapping subsamples. This allows us to monitor the evolution of the spillover indices (Eqs. (4)-(8)) over time, shedding light on the effect of significant global events on the interrelationships between the stock markets.

Figure 2 depicts a rolling-window analysis of the total spillover index among the six stock markets, showing the evolving financial integration in the LAIA region.[9] Different episodes of interconnection emerge, three of which are regarded as high-integration episodes.[10] The first episode covers the period from the beginning of the time series to July 1998, during which the spillover index oscillates between 52% and 54%. The second episode, from August 1998 to July 2003, corresponds to events such as the 1999 Brazilian currency crisis, the 2000-2022 technology bubble burst, and the 1998–2002 Argentine great depression and its aftermath, with

[8] As there is no consensus on the selection of the window length, the window size is fixed at 60 months, approximating the length of a full business cycle, as suggested by Billio *et al*. (2017), who also state: '*The window should be wide enough to leave sufficient observations to compute precise correlation coefficients but short enough in order to avoid smoothing out important medium-term changes in integration*'.

[9] The average value of the rolling-window version of the total spillover index is 62.53%, which is of the same magnitude as that of the full-sample analysis (59.61%), confirming the high degree of financial market integration among the examined countries.

[10] We identify three significant periods of high financial integration among equity markets: August 1998 to July 2003, October 2008 to September 2013, and March 2020 to April 2022, with the second period displaying the highest level of integration. Using Bai and Perron's structural change approach (results not reported), we identify five break dates in the total spillover index, shedding light on its evolution across six regimes. The second, fourth, and sixth regimes align with the high-integration episodes.

the spillover index fluctuating between 62% and 70%, exhibiting increases compared to the first episode. The third episode, from August 2003 to September 2008, incorporates the 2003-2008 oil price bubble, with a spillover index ranging from 52% to 62%. The fourth episode, which follows the Lehman Brothers event, is marked by a sharp rise in the spillover index, which peaks at 73% in October 2008 and remains relatively stable until September 2013, reflecting the impact of the global stock market collapse and associated economic uncertainties.[11] The fifth episode, which mirrors the 2014-2017 Brazilian economic crisis and the 2018 Argentine financial crisis, ranges between 58 and 59%, with a peak of 63% in 2014 and 2016. Finally, the sixth episode, spanning from the March 2020 COVID-19-induced stock market crash to the study's end, shows fluctuations between 62% and 67%, with the Russo-Ukrainian war marking the episode.[12]

In conclusion, the most crucial findings pertain to three high-integration periods, notably the period from October 2008 to September 2013. These episodes highlight how global and regional crises significantly affect financial integration among major LAIA region markets, impacting the potential benefits of equity portfolio diversification and supporting the idea of financial contagion.[13]

In our rolling-window analysis, we track the changing patterns of directional spillovers ("From others" given by Eq. (5) and "To others" given by Eq. (6)) among equity markets over time. Figure 3 shows that all six markets exhibit high spillover values, especially during the three high-integration episodes, reflecting the behavior of the total spillover index. Notably, Brazil, Chile, and Mexico consistently receive more information from other markets, while Figure 4 indicates that they also contribute more to the other markets compared to Argentina, Colombia, and Peru throughout most of the sample period. These results emphasize the dynamic nature of information flows and interrelationships among these markets.

The net directional spillovers in equity markets (given by Eq. (7) and depicted in Figure 5) are highly variable over time and vary in magnitude across markets and time periods. Consistently positive net spillovers from the Brazilian, Mexican, and Chilean stock markets indicate their function as net contributors to other markets. Particularly, Brazil emerges as the top net transmitter, followed by Mexico and Chile. Conversely, Argentine, Colombian, and Peruvian equity markets typically receive more influence than they provide, with negative net spillovers being the prevailing trend. The most significant net receiver is Colombia, followed by Argentina and Peru.

The analysis of net pairwise spillovers between two stock markets (given by Eq. (8) and plotted in Figure 6) reveals mixed net spillovers across country-pairs, except for Brazil-Colombia, where the spillover remains consistently positive, indicating that Brazil does not receive information from Colombia. Brazil emerges as the most influential (as evidenced in Figure 1),

[11] Wu (2020) finds that the level of interrelation between nine East and Southeast Asian equity markets reaches a peak of approximately 79% between early 2009 and mid-2013, illustrating the effects of the crises that occurred during that time period on the relationship between stock markets worldwide.

[12] Yousaf *et al*. (2023) reveal a significant increase in volatility connections among global financial markets due to the Russo-Ukrainian war, particularly in the short-term. In contrast, the impact of COVID-19 is more substantial and enduring across short, medium, and long-term periods.

[13] We have investigated the impact of the three high-integration episodes on the interrelationships of financial markets in the LAIA region, recognizing that portfolio diversification is especially important during turbulent periods. We have employed regression analysis and found statistically significant and positive coefficients for the dummy variables associated with these episodes. Specifically, during these periods, the average values of the spillover index reach 66.34%, 70.47%, and 64.40%, surpassing the total average value of 62.53%. This underscores that the benefits of portfolio diversification are contingent on the prevailing regime, emphasizing the need for caution when investing in these markets during volatile periods.

transmitting more information to other markets than it receives, while Colombia tends to receive more than it contributes, consistently experiencing negative net spillovers.

4. Robustness checks

To ensure the robustness of our conclusions regarding financial market integration among the sample economies, we have performed further tests that involve varying the lag length of the VAR model, the forecast horizon of the GFEVD method, and the window size of the rolling analysis, while retaining the baseline values for the remaining parameters. The static full-sample analysis (available upon request) shows that the overall interconnectedness of the stock markets remains consistent, fluctuating between 59.61% and 60.60%, and that directional spillovers ("From others", "To others", and "Net") exhibit similar patterns as in the baseline analysis.

The dynamic rolling-window analysis (Figures 7-9) indicates that variations in the lag length of the VAR model, forecast horizon, and window size have negligible effects on the total spillover index. The levels and trends of stock market integration are consistent across all specifications, with small differences observed.[14] The average total spillover indices, which range from 62.48% to 65.81%, closely match those from the baseline rolling-sample analysis (62.53%), affirming the results' robustness. In addition, the patterns of directional spillovers (not reported) remain comparable to the baseline analysis. In conclusion, both full-window and rolling-window analyses validate the reliability of the baseline findings and emphasize the market conditions' influence on portfolio diversification.

5. Conclusion and policy implications

The paper examines stock market integration among six major LAIA countries from 1993 to 2022, including events like the COVID-19 pandemic and Russo-Ukrainian conflict. Using Diebold-Yilmaz's methodology, it identifies the leading stock market among these economies and highlights evolving patterns of financial integration over time. The study provides important insight into the intermarket connections between Latin American economies. It shows a high level of stock market integration, particularly during major occurrences such as the Argentine Great Depression, the global financial crisis, the COVID-19 pandemic, and the Russo-Ukrainian conflict. During the global financial crisis, the highest levels of integration occurred, supporting the concept of financial contagion. In these markets, this reduces the benefits of diversifying equity portfolios. Notably, Brazil emerges as a significant influencer of stock market dynamics in the LAIA region, offering predictive value. Additionally, the study demonstrates the robustness of these relationships across various methodologies. The approach provides a comprehensive analysis of financial integration in six Latin American economies and may be relevant to the management of regional equity market integration.

The implications of the study's findings for policymakers and investors are critical. For policymakers, the findings underscore the challenge of achieving greater financial integration within the economies under consideration and the broader LAIA region. To address this issue, countries should align their goals and collaborate on various fronts, including harmonizing market practices, establishing multilateral mechanisms to facilitate intra-Latin American stock trading, integrating regulatory systems, and enhancing cross-border transaction infrastructure. Furthermore, the study recommends policy measures to manage crisis-related contagion risks, which will benefit not only the studied markets but the entire region. For investors, the findings provide valuable insights into portfolio diversification opportunities in the LAIA region.

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[14] The financial integration levels identified for the three values of the forecast horizon (Figure 8) are the same, as the total spillover indices are merged throughout the study period, indicating that changing the forecast horizon does not influence the levels and patterns of equity market integration.

Table 1. Spillover matrix (%)

	ARG	BRA	CHL	COL	MEX	PER	**From others**
ARG	45.58	13.09	12.03	6.11	13.61	9.58	54.42
BRA	10.54	35.29	15.71	8.87	15.63	13.96	64.71
CHL	10.12	16.74	38.02	9.72	12.92	12.48	61.98
COL	7.18	12.97	13.37	44.42	11.32	10.74	55.58
MEX	11.61	16.54	12.94	7.60	38.99	12.32	61.01
PER	8.60	15.87	13.59	8.74	13.14	40.06	59.94
To others	48.05	75.21	67.64	41.04	66.62	59.08	357.64
Net	-6.37	10.50	5.66	-14.54	5.61	-0.86	**Total: 59.61**

Notes: The diagonal elements are the own contributions of the stock markets; "From others" stands for the directional spillovers received by the stock market i $(i = 1, 2, \dots, 6)$ from all the other markets; "To others" represents the directional spillovers transmitted by the equity market i $(i = 1, 2, \dots, 6)$ to all the other markets; "Net" denotes the net spillover from the stock market i $(i = 1, 2, \dots, 6)$ to all the other markets, (i.e. the stock market's i net contribution to the whole system); and "Total" is the total spillover index (357.64/6).

Figure 1. Full-sample pairwise relationships for the stock market returns

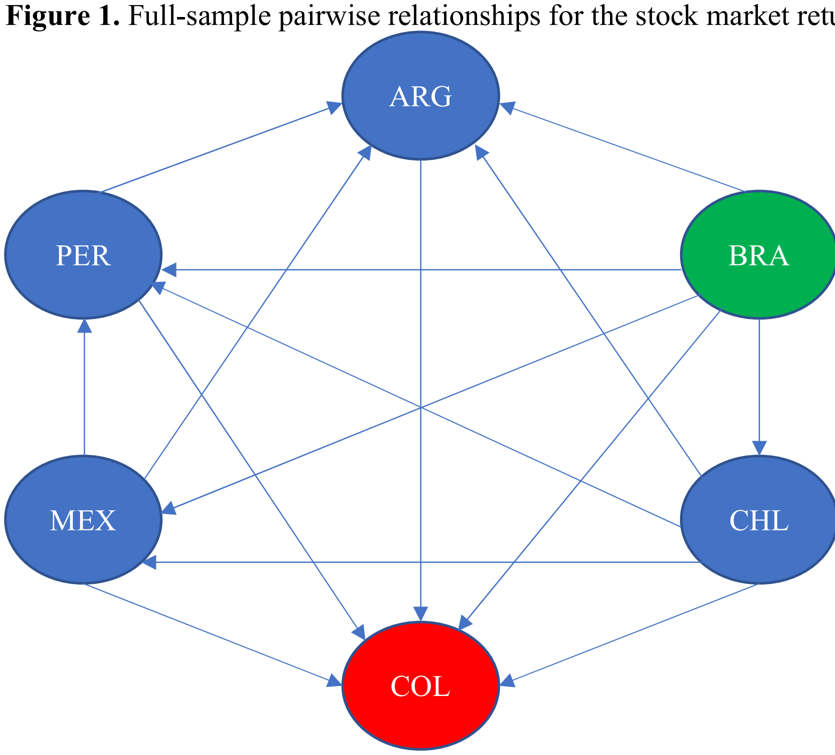


Figure 2. Rolling-sample total spillover index between the stock market returns

Figure 3. Rolling-sample directional spillovers, from all the other markets

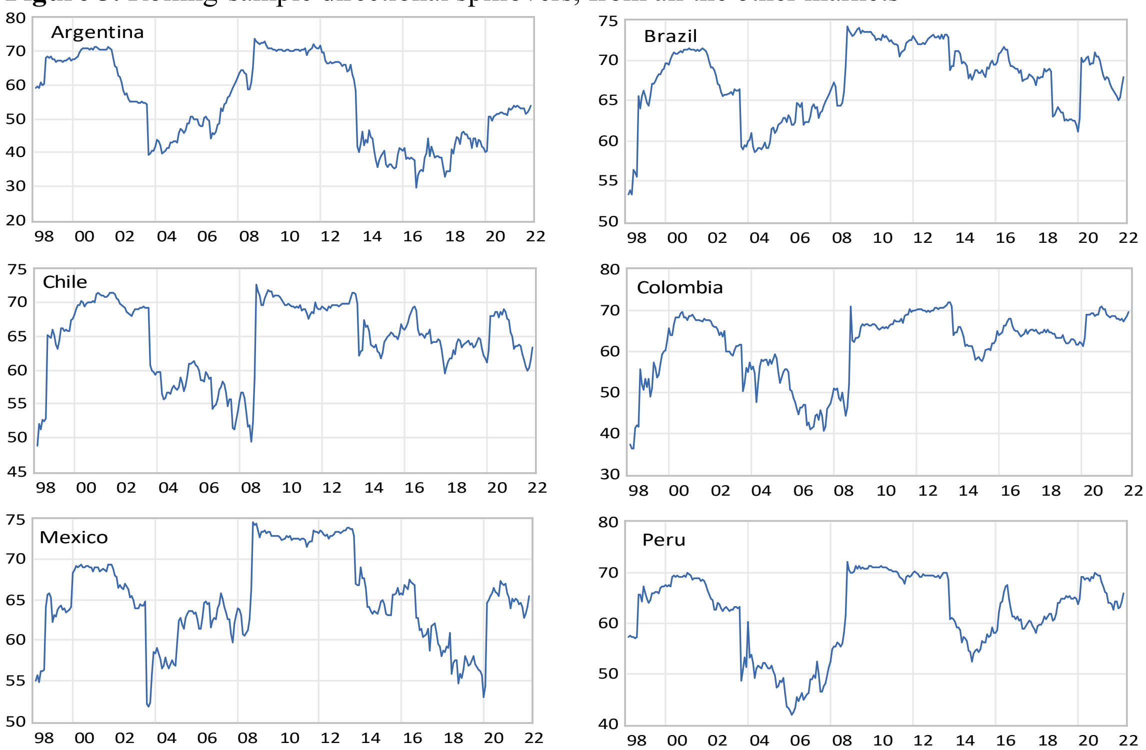


Figure 4. Rolling-sample directional spillovers, to all the other markets

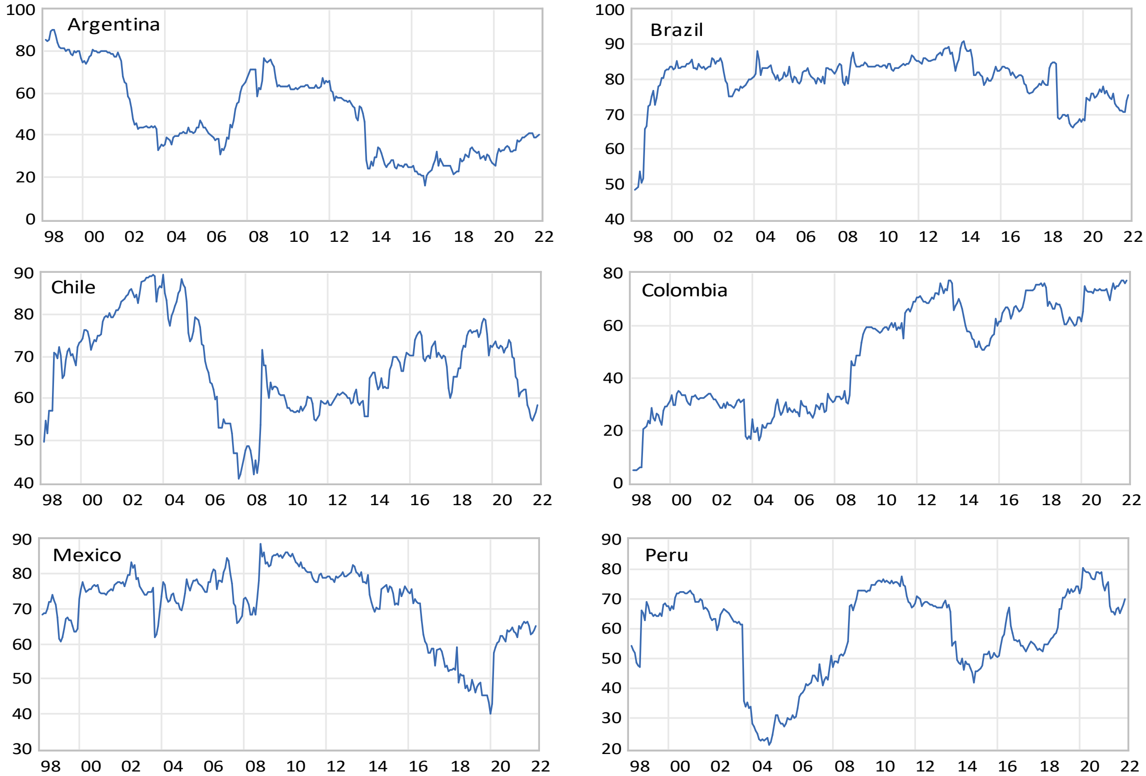


Figure 5. Rolling-sample net directional spillovers, all the other markets

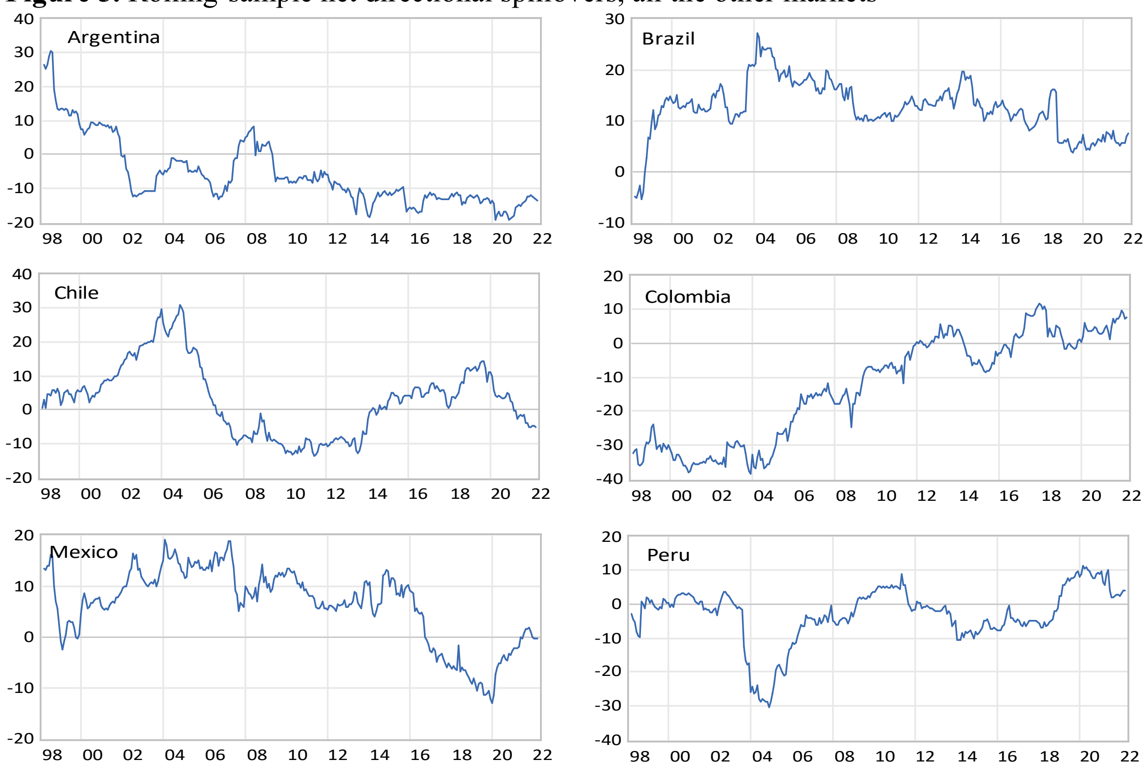


Figure 6. Rolling-sample net pairwise directional spillovers

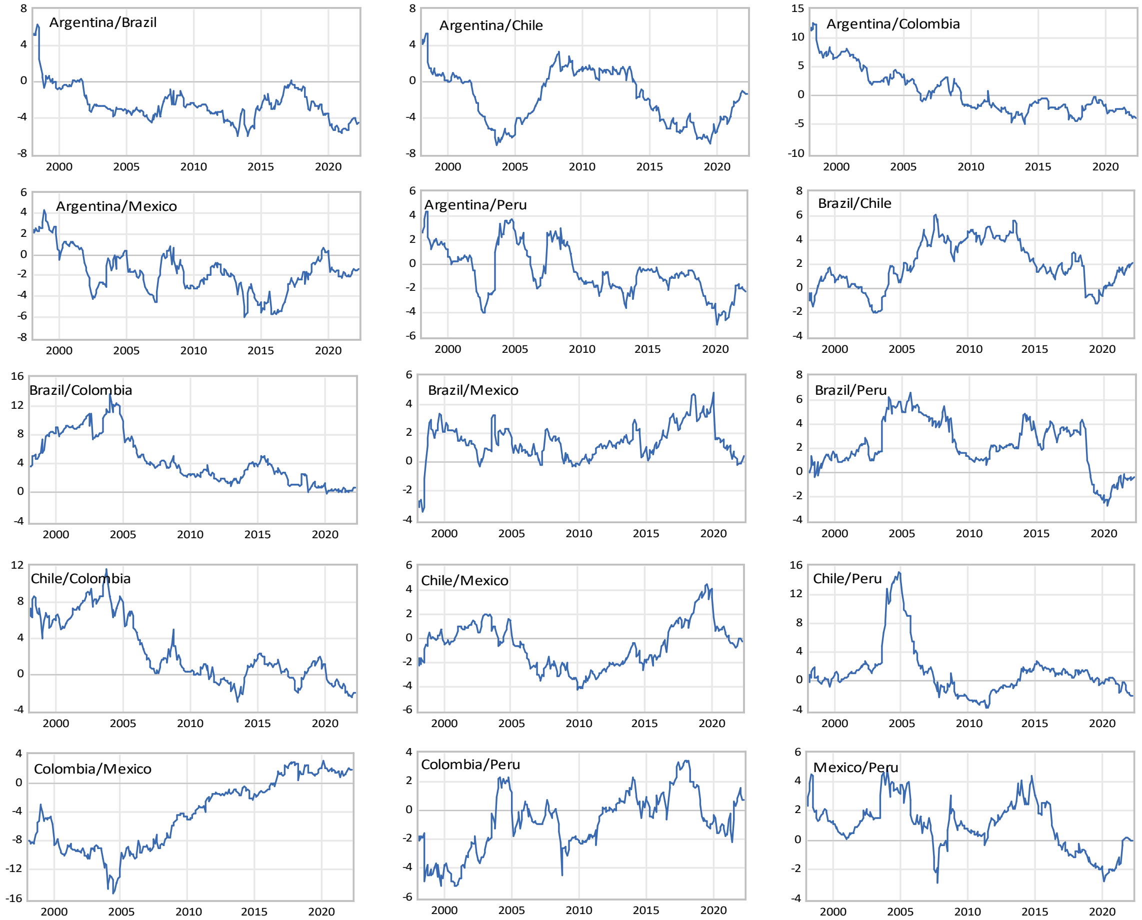


Figure 7. Sensitivity of the rolling-sample total spillover index to VAR lag length

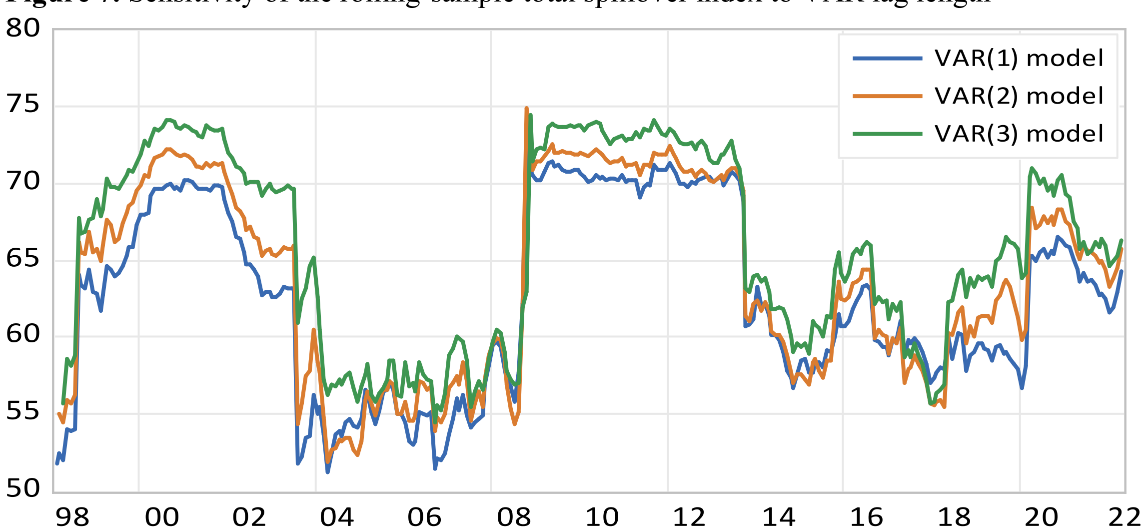


Figure 8. Sensitivity of the rolling-sample total spillover index to forecast horizon

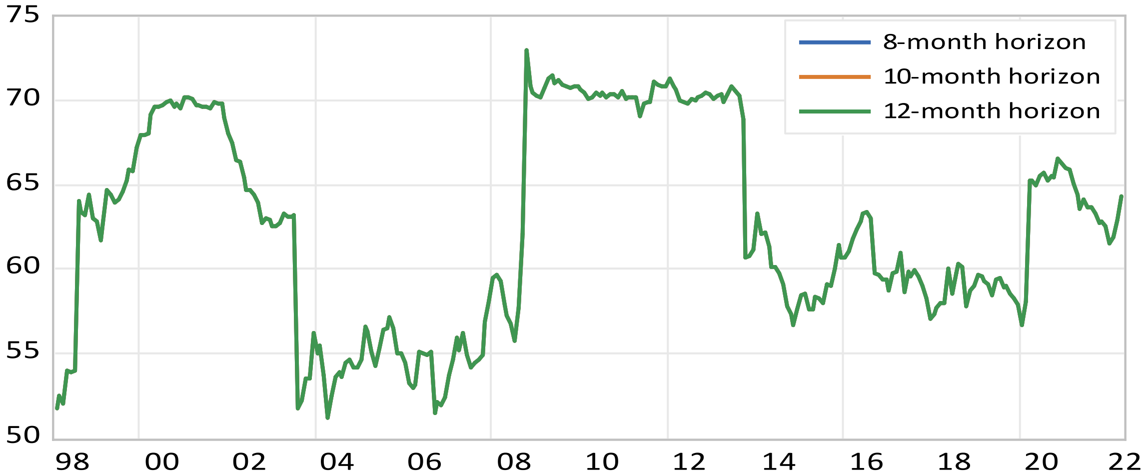
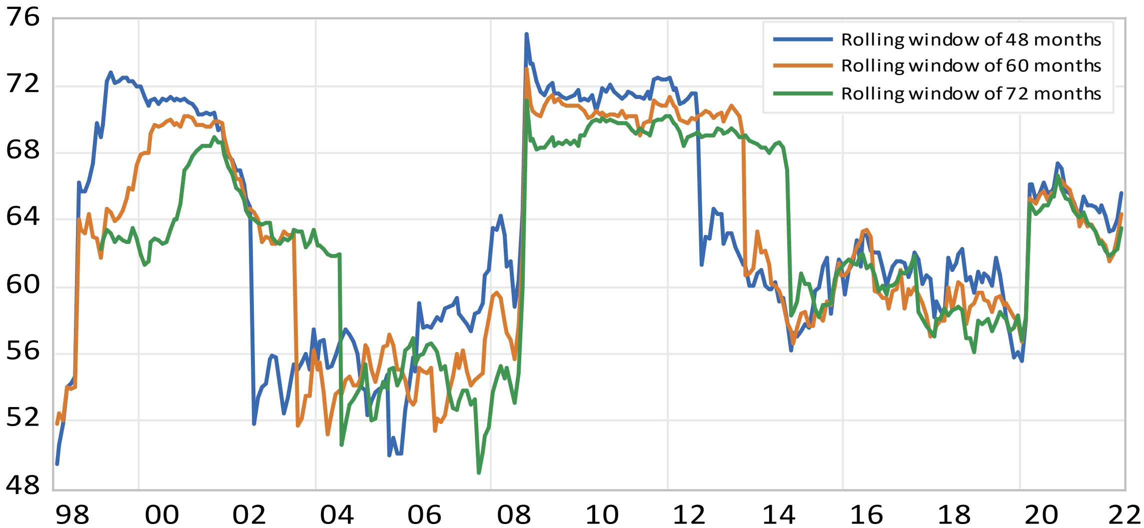


Figure 9. Sensitivity of the rolling-sample total spillover index to window size



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