Dynamics and Co-movements Between the COVID-19 Outbreak and the Stock Market in Latin American Countries: An Evaluation Based on the Wavelet-Partial Wavelet Coherence Model

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Abstract
The COVID-19 outbreak and the global uncertainty it causes produce an apparent panic in stock markets. Efforts to explain the economic spillover effects of COVID-19 can guide authorities to design a control policy against the financial impacts of pandemics. The paper examines the effects of the COVID-19 cases on the stock markets in the emerging Latin American countries of Argentina, Brazil, Chile, Colombia, Mexico, and Peru. The paper employs a continuous partial wavelet methodology to observe lead-lag relations between the daily variables of new COVID-19 cases and the stock market index for each Latin American country. Brazilian new COVID-19

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cases led the Bovespa (BVSP) index to decline during the whole period, except February and June 2020, at one month-two month-frequency band. The wavelet and phase difference analyses indicate that, except for Brazil, COVID-19 cases did not affect the stock market indexes adversely during the whole sample period but did affect the stock exchange markets negatively during some sub-sample periods of the entire sample of each country. Dynamics of Latin American stock exchange markets in the short and long run can be explained by some other parameters of real and financial sectors and COVID-19 cases.

**Keywords**
new COVID-19 cases, stock market, new COVID-19 deaths, exchange rates, SP500, emerging Latin American countries

**JEL Codes**
G1, G17, C40

**Introduction**
The new type of Coronavirus (COVID-19) outbreak, which started in Wuhan, China in December 2019, spread rapidly to Asian economies, then to America, Europe, and the whole World (Ghanbari, 2020). Due to the global contagion effect and increasing cases, the World Health Organization (WHO) declared the COVID-19 outbreak an official pandemic on March 11, 2020 (Chowdhury et al., 2022; Zhang et al., 2020). Since the first case, there have been 475,768,643 confirmed cases and 6,104,405 deaths worldwide (Johns Hopkins Coronavirus Resource Center, 2022). As the pandemic continues, there is unprecedented uncertainty around the World about the lethality impact of the disease, whether there will be a vaccine, and how long it will take to reach people if it occurs (Ashraf, 2020; Shahzad et al., 2022). The COVID-19 outbreak and its uncertainty undoubtedly led to severe disruptions in everyday life and economies (Lazzerini & Putoto, 2020). The uncertainty can affect the dynamics of the economy adversely. The increasing number of cases and deaths in various parts of the world every day caused panic and chaos in the real economy and financial markets on a global scale (Salisu & Akanni, 2020). As the first response to the outbreak, many goods and services sectors contracted, international supply chains were directly affected, consumer-producer confidence indices fell, and global trade volume shrunk (Hale et al., 2020). However, the economic area most affected by the COVID-19 outbreak is the stock markets (Koçak, Dogru, et al., 2022; Topcu & Gulal, 2020; Zhang et al., 2020). An important indicator of this situation is the
emergence of unprecedented volatility in the US stock markets at the end of March 2020. Also, the rise of the VIX volatility index, known as the global fear index, to levels above the 2007–2008 crisis is another evidence of the initial effects of COVID-19 on the stock market (Ciner, 2020). Although there is a preliminary indicator such as volatility in stock markets, information on the effects of the COVID-19 outbreak on financial markets and stock returns is currently very limited and short-run (Arias, 2020; Cepoi, 2020); therefore, explaining the dynamic effects of the COVID-19 outbreak, and the number of cases and deaths on financial markets will make an essential contribution to the literature. Some papers declare that the impact of COVID-19 on financial markets may be more significant than the 2007–2008 Global crisis (Ciner, 2020; Shehzad et al., 2020). Goodell (2020) reveals that a pandemic may have devastating effects on financial markets. On the other hand, this situation is also an opportunity for researchers to investigate the pandemic-finance relationship. Globally, there is tremendous fear about the possible impact of the COVID-19 outbreak on financial markets and the economy (Goodell, 2020). In many countries, governments try to control the pandemic with health measures and restrictive policies. Governments also aim to reduce the negative impact of the epidemic on the economy and financial markets with various financial and economic incentives. Explaining the dynamics and co-movements between COVID-19 and financial markets can guide the authorities in developing policies for financial markets.

With COVID-19, much research has been undertaken on the relationship between the pandemic and stock markets. In the current literature, some studies focus on developed markets, while others examine emerging markets, especially Asian ones. Some studies analyze the relationships between COVID-19, the global fear index, economic policy uncertainty, and stock returns. Other papers focus on the spillover effects between COVID-19 and the stock market. The effects of COVID-19 on sectoral stocks such as industry, technology, transportation, tourism, and defense industry are also examined. The findings are summarized as follows when the available literature is reviewed.

He et al. (2020b) examine the direct effects and spreads of COVID-19 on the stock markets for the stock markets of China, Italy, South Korea, France, Spain, Germany, Japan, and the United States. The findings show that COVID-19 has a negative but short-term impact on the stock markets of the affected countries and that the impact of COVID-19 on the stock markets has bidirectional spillover effects between Asian countries and Europe. Topcu and Gulal (2020) examine the impact of COVID-19 on the stock markets of emerging market economies. Empirical results show that the highest impact is in Asia and the lowest is in European emerging markets. The paper also underlines that the official response time and the size of the stimulus package provided by governments are essential in balancing the effects of the
pandemic. Narayan et al. (2020) investigate the relationship between the Japanese yen and the stock market during the pandemic. The research reveals that the yen’s depreciation against the US dollar increased in Japanese stock returns. Mazur et al. (2021) discuss the relationship between COVID-19 and the US stock market return and volatility within the S&P 1500. According to the findings, natural gas, food, health, and software stocks have high positive returns, while oil, real estate, entertainment, and accommodation stock’s yields decrease. Okorie and Lin (2021) analyze the fractal contagion effects of COVID-19 on stock markets in 32 countries. The research reveals significant fractal contagion effects on the return and volatility of stock markets. Li et al. (2021) examine the relationship between pandemic fear and stock market returns for developed country stock markets. The findings reveal that stock trading depends on the case index, the death index, and the global fear index.

Remarkably, it is observed that there is low interest in the literature about the response of the stock markets of Latin American countries to the pandemic, and there is a research gap. Latin American stock markets show the characteristics of an emerging market economy, and there is a need for research on the pandemic-stock market nexus. Based on this imperative, we aim to investigate the influence of the COVID-19 pandemic on the stock markets in Latin American Emerging countries using a wavelet approach. With the employment of Latin American Emerging countries data, this work follows the wavelet transform to investigate the co-movements of the variables throughout the sub-samples and whole sample periods associated with low and high-frequency bands. The contribution of this paper to the literature is in three-folds: (1) One of the regions where the pandemic is most affecting is Latin America. As of March 2022, Argentina, Brazil, Colombia, Chile, and Mexico have the highest number of confirmed cases of COVID-19. According to other essential statistics, Brazil, Mexico, Argentina, Peru, and Colombia are among the countries where deaths from COVID-19 are most common (Johns Hopkins Coronavirus Resource Center, 2022). It is a remarkable region to learn about the economic and financial implications of COVID-19. Moreover, there exists a research gap regarding the co-movement and dynamic effects of the impact of COVID-19 on stock markets in the Latin American region. Therefore, we expect the outputs of this article to contribute to the literature by revealing added information.

(2) There are arguments in the literature that COVID-19 may cause a fractal contagion effect between stock markets (Okorie & Lin, 2020). For this reason, we also investigate how Latin American financial markets respond to the change in global stock markets, along with the COVID-19 case and death numbers. We consider the SP500 or the Standard and Poor’s 500 indexes to represent the change in the global stock market. The SP500 is an index that considers the market capitalization weight of the 500 largest US companies publicly traded. The index is considered the best indicator of the wide range of
US stocks and represents the global stock market. The estimation findings will reveal how the stock exchange in each Latin American country reacted to changes in the SP500 during the COVID-19 outbreak and whether there was a spillover effect on financial markets.

(3) Recently, the novel coronavirus and its impact on financial markets have attracted significant interest from many researchers. Various estimators are used to deepening understanding and insight of valuable inferences through mathematical and statistical modeling. Mathematical and statistical modeling is a critical tool for analyzing the spread and knowledge of the manageability level and impact of the prevention and control mechanisms applied to the pandemic (Boukanjime et al., 2020). The susceptible exposed infectious recovered (SEIR) model is often used to describe the dynamics of the pandemic based on the progression of COVID-19 and quarantine response measures (Annas et al., 2020; Hou et al., 2020). Computable general equilibrium models are used to explain the behavior of COVID-19 and its effects on prices and the overall economy (Aydin & Ari, 2020; Keogh-Brown et al., 2020). Time series analysis and various panel data methods are followed to explain the dynamic effects of the pandemic on the real economy and financial markets (Al-Awadhi et al., 2020; P He et al., 2020; Liew, 2020; Lobão et al., 2022; Okorie & Lin, 2020). This paper analyzes the dynamic effects of COVID-19 on the financial market, with a wavelet and partial wavelet consistency. It thus provides information about the wavelength where (a) significant co-movements between variables can be observed and (b) lead-lag correlations of the variables are seen. Therefore, our estimation model is an ideal way to learn the impact of the COVID-19 outbreak on stock price movements and volatility.

The rest of the research is organized as follows. After the introduction, the second section explains the materials and method. Section three sets out the data and forecast findings. Section four, the conclusion section, provides the research results and offers recommendations to politicians and future research.

**Materials and Method**

**Wavelet Analysis**

Wavelet analysis technique has been applied intensively by researchers, especially in recent years (Bilgili, 2015; Bilgili et al., 2019, 2020, 2021a, 2021b, 2022; Kassouri et al., 2022; Kuşkaya, 2022; Kuşkaya et al., 2022; Kuşkaya & Bilgili, 2020; Magazzino & Mutascu, 2019; Magazzino et al., 2021; Magazzino & Giolli, 2021; Mutascu et al., 2022; Shehzad et al., 2021). Wavelet transform is one of the most followed frequency analysis methods to analyze non-stationary time series (Cohen, 2019). Wavelet can simultaneously localize signals in the time and frequency domain. As the best technique for
the non-stationary time series, the wavelet transform is filtered into different frequency bands divided into segments in the time domain (Zhao et al., 2004). Wavelet analysis can discrete the data of the fluctuations into various frequency components by considering the time and scale domain simultaneously (Crowley, 2005). The wavelet function $W_{(s,n)}(t)$ is defined as (Matalgah et al., 1997)

$$W_{(s,n)}(t) = \frac{1}{\sqrt{n}} \int_{-\infty}^{\infty} x(t) b^* \left(\frac{t - s}{n}\right) dt$$  \hspace{1cm} (1)

The $n$ is the scaling parameter and $s$ is the shifting parameter. The term $x(t)$ is called analyzing wavelet. In equation (1), the term $1/\sqrt{n}$ used to ensure energy conservation. Also, $b^*$ is the complex conjugate of the mother wavelet function $b(t)$ which provides the balance between both domains. Morlet wavelet transform, one of the wavelet types, is a transformation that includes two parts; imaginary and real. Morlet wavelet transform is defined by Torrence et al. (1998) as below

$$b^w(t) = pi^{-1/4}e^{i6t}e^{-\left(\frac{t^2}{2}\right)}$$  \hspace{1cm} (2)

Cross-wavelet transform (CWT) is utilized to reveal time-frequency analysis information between two non-stationary time series and to determine their power and phase difference in time-frequency domains (Firouzi & Wang, 2019). The CWT can be defined as equation (3)

$$W^{x,y}(s,n) = W^x(s,n)W^y*(s,n)$$  \hspace{1cm} (3)

Cross-wavelet power determines the areas where the correlation between the {X} and {Y} has high common power (Grinsted et al., 2004). Wavelet coherence of two time series of $W^x(s,n)$ and $W^y(s,n)$ can be defined in equation (4) as is depicted by Aguiar-Conraria et al. (2013)

$$\mathcal{N}^{xy}(s,n) = \left(\frac{|S(w^{xy}(s,n))|}{\sqrt{|S(w^x(s,n))|S(w^y(s,n))}}\right)$$  \hspace{1cm} (4)

where $\mathcal{N}^{xy}$ indicates the correlation, this parameter ranging from 0 to 1. $S$ denotes the smoothing operator.

The partial wavelet (PW) coherence is a technique similar to the partial correlation that helps find the resulting wavelet coherence between {Y} and {X1} after eliminating the influence of the {X2} (Mihanović et al., 2009). The partial wavelet coherence squared is defined as

$$\left(PW_{(x1,x2)}\right)^2 = \frac{|W_{yx1} - W_{yx2}.W_{x2x1}|^2}{\left(1 - (W_{yx2})^2\right)\left(1 - (W_{x2x1})^2\right)}$$  \hspace{1cm} (5)
\[
\left( PW_{xyx} \right)^2 = \frac{\left| W_{yx2} - W_{yx1} \cdot W_{x2}^* \right|^2}{(1 - W_{yx1}^2)(1 - (W_{x2})^2)}
\]

One can define the complex wavelet coherency as follows (in analogy with the concept of coherency used in Fourier analysis), given two-time series \(x(t)\) and \(y(t)\), as is explained in Aguiar-Conraria et al. (2013)

\[
\varphi_{xy} = \frac{S(W_{xy})}{\left[ S(|W_x|^2) S(|W_y|^2) \right]^{1/2}}
\]  

(6)

where \(\varphi_{xy}\), \(W_x\), \(W_y\) and \(W_{xy}\) are complex wavelet coherency, the wavelet transforms of \(x\) and \(y\), and the cross wavelet transforms of \(x\) and \(y\), respectively. The parameter \(S\) depicts a smoothing operator in both time and scale. The \(S\) is required; otherwise, the coherency would be identically one at all scales and times. One can define the wavelet coherency by taking the absolute value of the complex wavelet coherency denoted by \(\mathcal{S}_{xy}(\hat{s}, \hat{f})\)

\[
\mathcal{S}_{xy}(\hat{s}, \hat{f}) = \frac{|S(W_{xy})|}{\left[ S(|W_x|^2) S(|W_y|^2) \right]^{1/2}}
\]  

(7)

In the model, phase difference analysis is used to detect phase coherences between variables. The phase difference \(^1 (\beta_{x,y} \in [-\pi, \pi])\) among \(\{X\}\) and \(\{Y\}\) can be described as follows

\[
\beta_{x,y} = \arctan \left[ \frac{\text{Im}(w_{xy}(s,n))}{\text{Re}(w_{xy}(s,n))} \right]
\]  

(8)

In equation (8), \(\text{Im}(w_{xy})\) and \(\text{Re}(w_{xy})\) demonstrate imaginary and real parts of the smooth power spectrum, respectively. Phase angles \(\beta_{x,y} \in \left(0, \frac{\pi}{2}\right)\) demonstrate that the series move in-phase and the second variable \(y\) is lagging. Phase angles \(\beta_{x,y} \in \left(0, -\frac{\pi}{2}\right)\) demonstrate that the series move again in phase then the first variable \(x\) is lagging.

By following Aguiar-Conraria and Soares (2014), we can define complex partial wavelet coherency and partial phase difference. In the three-variable case, we depict the complex partial wavelet coherency by equation (9) as follows

\[
\partial_{12,3} = \frac{\partial_{12} - \partial_{13} \partial_{23}}{(1 - R_{13}^2)(1 - R_{23}^2)}
\]  

(9)
We denote the complex partial wavelet coherency between \( x(t) \) and \( y(t) \) after controlling \( z(t) \) as follows

\[
\partial_{xy,z} = \frac{\partial_{xy} - \partial_{iz}\partial_{jz}}{\left(1 - R_{ix}^2\right)\left(1 - R_{yz}^2\right)}^{1/2}
\]

(10)

By defining the complex partial wavelet coherency, \( \partial_{1j,qj} \), between series \( x_1 \) and \( x_j \) after controlling the remaining variables, we can define the partial phase difference of \( x_1 \) over \( x_j \), \( \vartheta_{1j,qj} \), as the angle of \( \partial_{1j,qj} \), as follows

\[
\vartheta_{1j,qj} = \tan^{-1}\left(\frac{\Im\left(\partial_{1j,qj}\right)}{\Re\left(\partial_{1j,qj}\right)}\right)
\]

(11)

**Data**

This paper employs the methodology of the Morlet wavelet transform model to analyze the co-movements between COVID-19 cases and the stock markets of Argentina, Brazil, Chile, Colombia, Mexico, and Peru. The paper also adds the variables of COVID-19 deaths, exchange rates, and SP500 of each country into the wavelet models as control variables. Data, source, and period for each country are given in Table 1.

**Estimation Outputs**

The outputs of partial wavelet coherency estimations are given in Figures 1–6. In the figures, the thick black lines represent the cone of influence, indicating the region influenced by edge effects. The color code for power varies from blue to red. The red and blue colors denote the strong association (power) and the weak association, respectively. The higher frequency (1 week–1 month) band outputs of phase difference analyses are shown in Figures 1(a)–6(a). The lower frequency (1 month–2 months) band outputs of phase difference analyses are exhibited in Figures 1(b)–6(b).

Figure 1 gives the findings of partial wavelet coherency between Argentina’s new COVID-19 cases and Merval (Argentina’s stock market index) with the control variables of Argentina’s new COVID-19 deaths, USD_ARS (exchange rate), and SP500 (the US stock market index).

Figure 1 yields lead-lag relations of the variables at a 1 week-1 month frequency band. Figure 1(a) exhibits the lead-lag relations of the variables at 1 month-2 months frequency band. Following the outputs from partial wavelet and phase difference analyses, one might reach the below wavelet coherency results for Argentina:
A negative association exists between new COVID-19 cases and Merval during the second half of April and the first half of May 2020. During this period, this finding reveals the negative impact of new COVID-19 cases on Merval. The new COVID-19 cases lead the Merval index (and, the Merval

| Country   | Variable                  | Source                                      | Date of Access                  |
|-----------|---------------------------|---------------------------------------------|---------------------------------|
| Argentina | New COVID-19 cases        | European Centre for Disease Prevention and Control | October 14, 2020                |
| (March 13, 2020-October 8, 2020) | New COVID-19 deaths | Investing database                          | October 14, 2020                |
| Brazil    | New COVID-19 cases        | European Centre for Disease Prevention and Control | October 14, 2020                |
| (February 26, 2020-October 8, 2020) | New COVID-19 deaths | Investing database                          | October 14, 2020                |
| Chile     | New COVID-19 cases        | European Centre for Disease Prevention and Control | October 14, 2020                |
| (March 4, 2020-October 8, 2020) | New COVID-19 deaths | Investing database                          | October 14, 2020                |
| Colombia  | New COVID-19 cases        | European Centre for Disease Prevention and Control | October 14, 2020                |
| (March 16, 2020-October 8, 2020) | New COVID-19 deaths | Investing database                          | October 14, 2020                |
| Mexico    | New COVID-19 cases        | European Centre for Disease Prevention and Control | October 14, 2020                |
| (January 14, 2020-October 8, 2020) | New COVID-19 deaths | Investing database                          | October 14, 2020                |
| Peru      | New COVID-19 cases        | European Centre for Disease Prevention and Control | October 14, 2020                |
| (March 9, 2020-October 8, 2020) | New COVID-19 deaths | Investing database                          | October 14, 2020                |
| All countries | SP500                   | Investing database                          | October 14, 2020                |

(i) A negative association exists between new COVID-19 cases and Merval during the second half of April and the first half of May 2020. During this period, this finding reveals the negative impact of new COVID-19 cases on Merval. The new COVID-19 cases lead the Merval index (and, the Merval
(ii) There also exists a negative correlation between new COVID-19 cases and Merval from the second half of August to October 8, 2020 (the end of the sample). During this period, this finding shows the negative impact of Merval on new COVID-19 cases in Argentina. The Merval leads the new COVID-19 cases (and the new COVID-19 cases are lagging).

Figure 2 reveals the outputs of partial wavelet coherency analyses between Brazilian new COVID-19 cases and Bovespa (BVSP) (Brazilian stock market) with the control variables of Brazilian new COVID-19 deaths, and Brazilian exchange rate (USD_BRL), and SP500 for the period February 26, 2020–October 8, 2020. Figure 2(a) yields lead-lag relations of the variables at a short-term cycle (at 1 week–1 month frequency). Figure 2(b) exhibits the lead-lag relations of the variables at a longer-term cycle (at 1 month–2 months frequency). The outputs from partial wavelet and phase difference analyses give the following wavelet coherency results for Brazil:
There is a negative association between new COVID-19 cases and Bovespa (BVSP) from mid-March 2020 to October 8, 2020, except in June 2020 at 1 month–2 months-frequency band. Partial wavelet coherency computations indicate no co-movement between the variables during June 2020 in the month–2 months-frequency band. Figure 3 reveals the outputs of partial wavelet coherency analyses for Chile for the variables of new COVID-19 cases and CLX_IPSA (stock market) with the control variables of new COVID-19 deaths, USD_CLP, and SP500 for the period March 4, 2020–October 8, 2020. Figures 3(a) and (b) show the lead-lag relations of the variables at a higher frequency and lower frequency, respectively. The findings of partial wavelet and phase difference analyses for Chile are:

(i) There is no negative association between the variables during both 1 week–1 month frequency band and 1 month–2 months-frequency band. (ii) There are primarily positive co-movements between the variables at both high and low-frequency bands.

Figure 2. (a) Partial Wavelet Coherency: Brazil New COVID-19 Cases/Brazil Stock Market || New Deaths; USD_BRL; SP500. (b) A week–A month Frequency Band, (c) 1 month–2 months Frequency Band.

Figure 3 reveals the outputs of partial wavelet coherency analyses for Chile for the variables of new COVID-19 cases and CLX_IPSA (stock market) with the control variables of new COVID-19 deaths, USD_CLP, and SP500 for the period March 4, 2020–October 8, 2020. Figures 3(a) and (b) show the lead-lag relations of the variables at a higher frequency and lower frequency, respectively. The findings of partial wavelet and phase difference analyses for Chile are:

(i) There is no negative association between the variables during both 1 week–1 month frequency band and 1 month–2 months-frequency band. (ii) There are primarily positive co-movements between the variables at both high and low-frequency bands.
Figure 4 yields the partial wavelet coherency analysis results for Colombia between new COVID-19 cases and the Colombian stock market (COL_CAP) with the control variables of new COVID-19 deaths, USD_COP, and SP500 from March 16, 2020, to October 8, 2020. Figures 4(a) and (b) plot the lead-lag relations of the variables at a shorter and longer regime, respectively, during the same period. The results are as follows:

(i) There is a negative lead-lag relation between new COVID-19 cases and COL_CAP during September and October 2020 at a longer cycle. The COVID cases are leading COL_CAP at this period. (ii) There is also a negative lead-lag relation between new COVID-19 cases and COL_CAP during June (second half), July, and August (first half). The COVID cases are lagging behind the COL_CAP during this period.

Figure 5 shows the partial wavelet coherency computations’ results for Mexico. The analyses observe the coherency between new COVID-19 cases and the Mexican stock market (BMV_IPC) with control variables new deaths
due to the COVID-19 pandemic, USD_MXN, and SP500 for the period January 14, 2020–October 8, 2020. Figures 5(a) and (b) refer to the lead-lag associations between the variables at a higher frequency and lower frequency, respectively. The outputs of the analyses indicate a negative association between new COVID-19 cases and BMV_IPC and COVID-19 cases lead to BMV_IPC during August, September, and October 2020.

The partial wavelet coherency estimations’ results for Peru are given in Figure 6. The analyses observe the possible strong or weak coherency between the new COVID-19 cases in Peru and the Peru stock market (Lima_General) through the control variables of new COVID-19 deaths, USD_PEN, and SP500 for the period March 9–October 8, 2020. Figures 6(a) and (b) yield the phase difference analyses at short and long regime, respectively. Throughout the analyses, one might state that;

(i) There appears to be negative coherency between the variables and new COVID-19 cases in Peru, leading Lima_General during September and August 2020. (ii) There is a negative correlation between the variables, and
new COVID-19 cases of Peru lag behind Lima_General during March, April, and May 2020.

The wavelet and phase difference analyses indicate that, except for Brazil, COVID-19 cases did not affect the stock market indexes adversely during the whole sample period but did affect the stock exchange markets negatively during some sub-sample periods of the whole sample of each country. These outputs agree with the following papers in the literature (Arias, 2020; Cepoi, 2020; Shehzad et al., 2020; Topcu & Gulal, 2020). Brazilian new COVID-19 cases lead the Bovespa (BVSP) index to decline during the whole period, except February and June 2020, at 1 month–2 month-frequency band. Hence, the outputs reveal as well that the dynamics of Latin stock exchange markets in the short run and long run can be explained by some other parameters of real and financial sectors as well as COVID-19 cases, and support the findings of the following papers (Bahloul

![Figure 5. (a) Partial Wavelet Coherency: Mexico New COVID-19 Cases/Mexico Stock Market BMV_IPC || New COVID-19 Deaths; USD_MXN; SP50. (b) A week–A month Frequency Band. (c) 1 month–2 months Frequency Band.](image-url)
Conclusion

The wavelet and phase difference analyses yield that, except for Brazil, COVID-19 pandemic cases did not adversely affect the stock market indices for the whole sample period but affected the stock markets negatively during some sub-sample periods of the entire sample of each Latin American country. The country-specific outputs of wavelet computations are as follows:

(a) The new COVID-19 cases in Argentina negatively affected the stock market in Argentina during just the period April 15–May 15, 2020. (b) Brazilian new COVID-19 cases led the Bovespa (BVSP) index to decline during the whole period except February and June 2020 at 1 month–2 month-frequency band. (c) There exist positive co-movements between the variables

Figure 6. (a) Partial Wavelet Coherency: Peru New COVID-19 Cases/Peru Stock Market Lima General || New COVID-19 Deaths; USD_PEN; SP500. (a) A week–A month Frequency Band, (c) 1 month–2 months Frequency Band.
in Chile. New COVID-19 cases in Chile lead to CLX_IPSA in May, June, and October 2020. (d) The COVID-19 cases lead COL_CAP to decline in Colombia during the last two months of the sample period. (e) The new COVID-19 cases lead BMV_IPC to decrease in Mexico during August, September, and October 2020. (f) New COVID-19 cases in Peru lead Lima_General to decline during September and August 2020.

The results also indicate that the dynamics of Latin American stock exchange markets in the short-regime and long-regime periods might be explained by some other relevant current and expected future parameters of commodity, financial, and health sectors as well as new (daily) COVID-19 cases such as expectations on the availability of COVID vaccine and/or herd immunity, among others. The emergence and rapid spread of the COVID-19 outbreak have witnessed a significant research challenge for various scientific fields around the world to slow or halt the growing trends of the spread of this disease (Zeroual et al., 2020). Another group of scientific research focuses on the social, financial, and economic impacts of COVID-19 (Bao & Zhang, 2020; Mnif et al., 2020; Williams, 2020). All these efforts will contribute to policymaking against possible global pandemics that may occur in the present and future. This research aims to contribute to the literature by examining the effect of COVID-19 on the stock market for rising Latin American countries.

Wavelet analysis used in the analysis has some limitations. (i) First, all the variables used in the analysis must have a high frequency. (ii) Scale selection in wavelet analysis is a highly complex process. (iii) An evident weakness of wavelet analysis in the zonal space is the inability to explicitly analyze waves at zonal wavenumber 0. (iv) Assessment of the statistical significance of the power peaks is complex and requires the specification of a background noise spectrum in the wavenumber frequency domain (Wong, 2009). Also, research has some limitations: (1) The current literature has dealt with larger stock markets such as China, Germany, the UK, and the USA. New research could explore the pandemic in other developing countries’ financial markets. (2) Future papers can address the impact of pandemics on the stock market at a sectoral level. Because some sectors may react positively to the pandemic, while others may respond negatively. (3) More mathematical, statistical, and econometric modeling methods must be used to explain the pandemic in all its aspects. Therefore, future research can follow structural break, time-varying linear and nonlinear time series analysis, and panel data methods. Mathematical and behavioral models such as partial equilibrium, general equilibrium, strategic decision-making, and game theory can be used. All these efforts will enrich the literature on pandemics’ social, economic, and financial impacts.
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Data Availability
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Note
1. The $\tan^{-1}$ is used in the equation (8) to indicate the following extension of the general main component of the $\tan^{-1}$ function ranges from $180\left(\frac{\pi}{2}\right)$ to $-180\left(-\frac{\pi}{2}\right)$ (Aguiar-Conraria & Soares, 2010):

$$
\tan^{-1}\left(\frac{m}{n}\right) = \begin{cases} 
  \tan^{-1}\left(\frac{m}{n}\right) & n > 0, \\
  \tan^{-1}\left(\frac{m}{n}\right) + \pi & n < 0, \quad m \geq 0, \\
  \tan^{-1}\left(\frac{m}{n}\right) - \pi & n < 0, \quad m < 0, \\
  \pi/2 & n = 0, \quad m \geq 0, \\
  -\pi/2 & n = 0 \quad m < 0,
\end{cases}
$$

Since the imaginary part is constantly zero in real-valued wavelet functions, the phase is undefined.

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