

NON-UNIFORM INTERCONNECTEDNESS PATTERNS AND DYNAMICS: EVIDENCE FROM EMERGING STOCK MARKETS

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Abstract: *In the last decades, past financial crises have proved that financial markets worldwide are interconnected, however the subject was scarcely analysed from the viewpoint of financial stock markets. Therefore, the paper aims to analyse interconnectedness between emerging stock markets. The methodology employed is the “Wavelet Local Multiple Correlation” as it allowed to introduce the dominance feature and to capture the time-varying shifts in correlations, as well as the non-uniform frequencies over time. The study involves five emerging markets worldwide for a long-time span from 2005 to 2024. The results report considerable variations within the correlation pattern, at different frequencies over time. Therefore, the findings display considerable evidence of interconnectedness and temporal dependence among the emerging stock markets.*

Keywords: emerging stock markets, interconnectedness, temporal dependence, Wavelet Local Multiple Correlation (WLMC)

JEL classification: F65, G11, G15

1. Introduction

In the last decades, past financial crises have proved that financial markets worldwide are interconnected; as Gofman (2017) argued, the financial systems have become “too interconnected to fail”. However, such interconnectedness among financial markets encompasses a major disadvantage namely, the risk spillover which is caused by negative externalities. In this sense, the interest for the study of interconnectedness increased considerably and was addressed by various scholars such as (Pretorius, 2002; Flavin et al. 2002; Phylaktis and Ravazzolo, 2002; Zeti 2014).

Martinez-Jaramillo et al. (2019) argued that interconnectedness could be viewed from both sides of the spectrum where one market could either absorb shocks or propagate them. Nonetheless, as stated in the literature, interconnectedness of financial stock markets is mainly driven by various factors that lay on the increased levels of global financial integration (which implies openness of capital flows, real and financial linkages, regional regulation systems, and so on).

The interconnectedness at the level of emerging markets was scarcely investigated in the literature, and a relatively low volume of studies could be identified such as, Kumar et al. (2023), Zhao et al. (2023), Okhrin et al. (2023), Roy et al. (2023), Younis, et al. (2024), Xiang and Borjigin (2024), Hoque et al. (2024), and Zargar et al. (2024), who found significant evidence of interconnectedness between the financial markets.

Liu (2013) researched the interdependence mechanisms in emerging markets and found that they are driven by economic integration, rather than financial dependences (such as, financial integration and investments). The concept of economic integration mainly implies the unification of trade and is assessed by taking into account the volume and intensity of bilateral trade. Hence, economic integration enhances the cash flows convergence from one economy to another, further leading to the synchronisation of the business cycles. Therefore, this convergence and synchronisation represents a mechanism of interconnectedness and fosters the emerging stock markets inter-relationships.

Younis et al. (2024) analysed the interconnectedness in stock markets and found that in periods of financial turmoil, the spillover effects are heightening. Also, they found that most of the emerging markets within their analysis were shock receivers, while the developed markets were shock transmitters. Their results reported that the equity markets were the transmitters of shocks to the commodity markets (such as, oil, gold, metals, energy, and so on).

Given the complexity of the subject, the methods used in the assessment of interconnectedness depend on two major factors, either the availability and type of data, or the kind of economic/financial activity (Raddant and Kenett, 2021). Therefore, the data involved in the measurement are the direct exposures data (which is often available only for regulatory and supervisory entities), and the publicly available data (such as the market prices). As Raddant and Kenett (2021) argued, one of the best methods to assess interconnectedness is based on the asset returns' correlation and their causality. In this sense, the correlation and causality could describe the systemic structure of the financial system and could boost potential transmission mechanisms and contagion channels. In this regard, this study focuses on analysing interconnectedness based on the co-movement patterns of different financial markets by employing a methodology that is able to capture and to identify the correlation between multivariate time-series, namely the Wavelet Local Multiple Correlation (WLMC).

The importance of the interconnectedness pattern in relation to time-frequency and dependence is instrumental for investors and other stakeholders, especially in the investment and diversification strategies. For instance, let's consider that the gold market in Country A is the leading market on the long run, while the financial stock market in Country A is the leader on the short run. The time-frequency analysis in this regard illustrates that diversification opportunities with gold imply advantages on the long run, so lower risk on the low-frequency scale.

On the same path, let's consider that the financial stock market in Country A is leading on the long run, while on the short run it is substituted by the stock market in Country B. Here, the time-frequency analysis reports instrumental information for stakeholders in taking investments decisions in Country A versus Country B based on their investment scope and risk aversion.

For a better assessment of interconnectedness in emerging stock markets, the dominance feature of market interrelations was introduced within the analysis. While interrelationships refer to co-movement in both directions, the “dominance” feature displays the precise direction of risk spillover, further identifying the causality from a specific market to another. Considering the time-varying nature of interconnectedness, it can be considered that dominance is also subject to temporal dependence (i.e. functional connection). Therefore, from both conceptual and methodological viewpoints, it is instrumental to acknowledge the possibility of dominance swaps overtime (for instance, long-term versus short-term), among emerging stock markets. In this sense, the Wavelet Local Multiple Correlations (WLMC) was a relevant methodology for the research, as it allows to identify and illustrate the dominance that could happen at the level of multivariate series’ dynamic interconnectedness.

The study proposes a three-fold contribution: (1) it aims to analyse interconnectedness in emerging stock markets and is meant to fill in a gap in the literature, as most studies focus on interconnectedness in other financial markets such as, the gold, oil and energy markets, currency and crypto-currency markets, and commodities market; (2) it significantly contributes to the literature through the methodology employed, the “Wavelet Local Multiple Correlation” (WLMC) (Fernández-Macho, 2018), that is able to capture the correlation patterns between time-series, and that adds-in the dominance feature of interconnectedness; (3) the study is meant to capture the potential non-uniform evolutive interconnectedness patterns, that could display a time-varying nature at different frequencies.

The study is built based on the following structure: the first section introduces some relevant literature upon the study of interconnectedness. The second section introduces the applied methodology, as well as the international data. The third section provides the empirical results, while the fourth section presents the conclusions.

2. Methodology and International data

2.1. Methodology

The study is build based on the “Wavelet Local Multiple Correlation” (WLMC) (Fernández-Macho, 2018), which was implemented based on the “VisualDom” R package (Polanco-Martínez, 2023) and “wavemulcor” R package (Fernández-Macho, 2022).

In the specific literature, the methodology was used to analyse the time-scale co-movement of different markets such as, the cryptocurrencies, the gold, wheat and cooper, and the oil and petroleum markets. Therefore, in the area of emerging stock markets analysis this methodology was scarcely used, although it encompasses significant advantages. First, the WLMC allows the analysis of data from the viewpoint of both time and frequency; thus, it could capture the pattern in the evolution of stock markets correlations and dynamics over time. Second, the WLMC can identify localized correlations between the stock markets' assets and their variations overtime due to specific market conditions. This fact is important in risk management as stakeholders could better manage their portfolio risk. Third, WLMC provides flexibility in capturing nonlinear and non-stationary relationships between stocks, making it suitable for analysing complex and dynamic stock market data.

Therefore, the motivation for selecting this methodology stands in its ability to capture the co-movement and interrelations between emerging stock markets, as well as the dominance within the multi-variate series' dynamic interconnectedness.

The detailed methodology is available within Fernández-Macho (2018) and Polanco-Martínez, (2023). However, the practical details for the implementation of the WLMC analysis are the following:

1. The weight (window) function selection – a Gaussian window was considered based on its properties (Fernández-Macho, 2018 and Polanco-Martínez, 2020).
2. The selection of the wavelet filter for MODWD estimation – the “Daubechies LA (8)” long wavelet filter was selected and considered more appropriate for the non-stationary correlation structures.
3. The variable that maximises the multiple correlation for every wavelet scale was chosen automatically by the implementation since the relationships among the markets' return dynamics are unknown.

2.2. International data

The dataset was built based on daily log returns for the period January 1st, 2005 – May 30th, 2024. This period encompasses the 2007-2010 global financial and real turmoil, the crisis triggered by the appearance of the COVID-19 coronavirus, and the post-2020 energy crisis and geopolitical instability. The dataset involves five emerging stock markets worldwide namely, IBOVESPA Index (Brazil), IPC Mexico (Mexico), SEE Composite Index (China), S&P BSE SENSEX (India), and JSE Limited (South Africa).

The data used for the analysis was taken from the “Yahoo Finance” (<https://finance.yahoo.com/>) publicly available database, by employing the R package “yfR” (Perlin, 2023). The data was synchronised by cutting off the non-available data, further resulting the input data of 3830 daily observations.

These emerging markets were selected as they play an instrumental role within the international financial system, for instance the economies of Brazil, India, China, and South Africa are members of the BRICS group of countries which represent a new source of diversification and investment opportunities. At the same time, these emerging markets play an instrumental role in the regional financial system as they boost economic growth, they offer opportunities for investment diversification, and they contribute to financial stability and foster the economic integration within the region.

As these markets are mainly chosen by international investors to trade their assets for portfolio diversification purposes, these markets absorb the shocks from developed markets and further transfer it within their geographic proximity. In this sense, it could be considered that these markets imply a significant degree of functional integration, meaning co-dependence of prices and returns due to portfolio diversification processes. Hence, these emerging markets might display evidence of functional interlinkages between them, being subject to non-linear, time-varying co-movements.

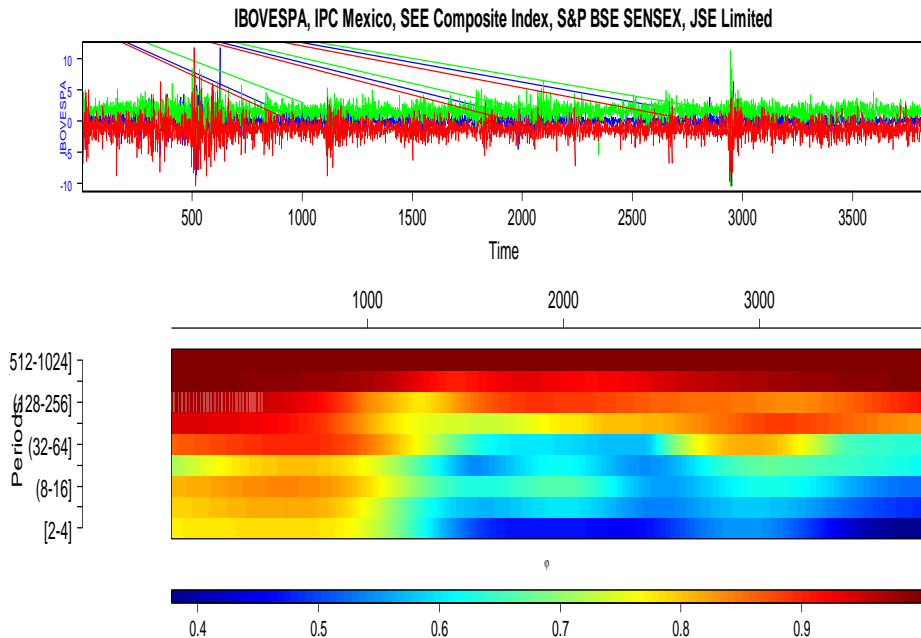
3. Main results

By employing the WLMC method, the study aims to analyse the dynamic relationship between the five emerging markets in terms of time and frequencies. The correlation coefficients report a significantly high correlation between the involved emerging stock market indices, varying from 0.38 to 0.99. However, the correlation is not homogenous for the entire time series length, as significant spans prove the heterogeneity of the results.

The first half of Figure 1 illustrates the WLMC for the return series, results that display similar return patterns throughout the analysed period, as well as strong correlation among the emerging stock markets. The second half of Figure 1 illustrates the wavelet correlation coefficients' "heat-map". It displays the heterogeneity of the correlation structure, the dynamic non-uniform nature of the returns' relationship in terms of time and frequency.

On the figure there are at least two significant frequency spikes where correlations coefficients are quite lower, on the short to medium term, namely around 2008 and during 2019. Consequently, the highest correlation coefficients' levels are caught on the long term (on the annual scale, and from 2 to 4 trading years).

Figure 1: The wavelet correlation coefficients' "heat-map"



Source: The wavelet correlation coefficients' "heat-map" at a confidence interval of 95%. Results are derived through the Daubechies wavelet of length $L=8$, and times and scales are displayed in days.

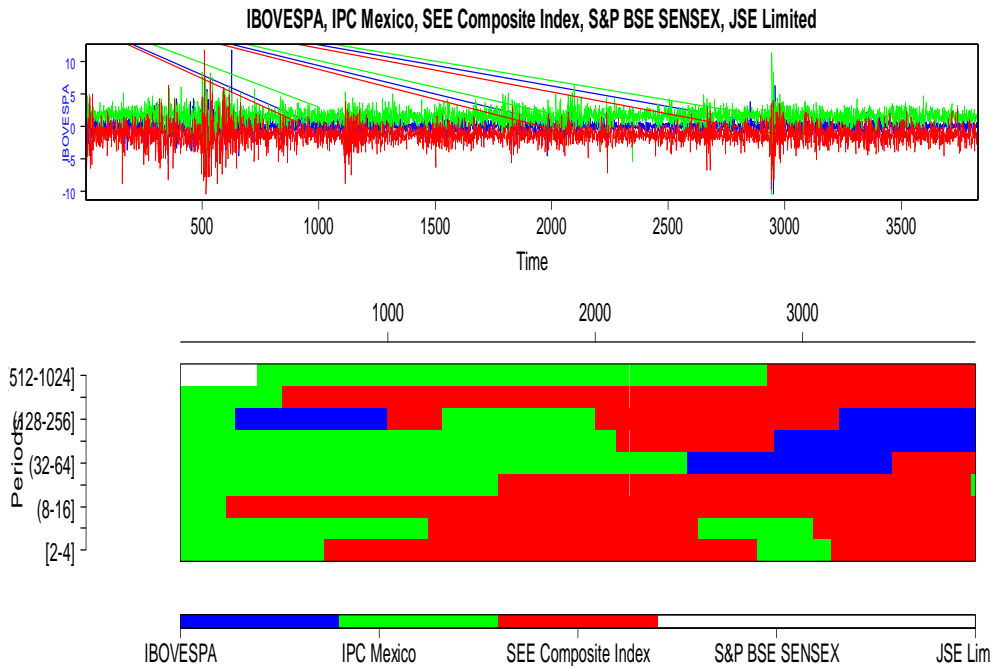
Figure 2 displays the dominant variables in time-frequency. On the short run, meaning intra-week scales (from 2 to 4 days), weekly scales (from 4 to 8 days), and monthly scales (from 16 to 32 days), the system is dominated by SEE Composite Index and to a lesser extent by IPC Mexico. On the quarterly scales (from 32 to 64 days), the system is mainly dominated by IPC Mexico, by Ibovespa to a lesser extent, and even less by SEE Composite Index.

On the long run, SEE Composite Index maintains its dominant position in the system. However, IPC Mexico also displays significant dominance evidence, followed by Ibovespa to a lesser extent. An important result here is that for the highest time scale (from 2 to 4 trading years), the dominance of SEE Composite Index is overpassed and substituted by IPC Mexico.

Another significant observation based on the results in Figure 2 is that JSE Limited and S&P BSE SENSEX do not report any significant dominance.

By summing up, on the short run the main dominant market is the Chinese one, while the main dominated markets are the emerging stock markets in India, South Africa, and Brazil. On the long run, the Mexican stock market is the dominant one, while the dominated emerging stock markets are in India, South Africa, and Brazil.

Figure 2: Dominant variables in time-frequency



Source: Based on the same specifications in Figure 1, this figure displays the dominance changes in time.

4. Conclusions

The results prove the functional integration of the emerging financial markets within the analysis. The stock markets are functionally connected (i.e. they are subject to temporal dependence) over the analysed period and the correlation pattern varies in time at different frequencies. Even though the analysis does not aim to study the factors that lead to such variations, it is important to highlight that the fluctuations in frequency occur during and post negative events (such as the global financial crises in 2008-2010, the period of increased volatility in 2018, and the post-2019 turmoil periods). These frequency fluctuations that occur especially on the short run, at lower timescales, prove the non-stationary nature of the time-series and could be considered as decoupling periods among the emerging stock markets.

An important observation is given by the substitution of the dominant emerging markets on the low timescale compared to the high timescale. In essence, the factors that drive short-term dominance, such as fleeting market sentiment or specific events, may not necessarily translate into sustained long-term dominance, which requires a broader set of economic, structural, and geopolitical factors. Nonetheless, the substitution of the dominant emerging markets reflects the dynamic nature of global finance and the ever-changing interplay of economic, political, and market forces.

The results imply several policy implications for various stakeholders such as, policymakers, investors, and financial institutions, that could help them overcome potential risks by capturing and accounting for the shifts in correlation patterns overtime.

From the viewpoint of investors, the results have significant implications in the area of asset allocation and diversification and portfolio management strategies. They should consider the time-dependences and frequencies patterns in order to take investment decisions that follow their long-term and/or short-term scope, the risk mitigation and the return maximization. Also, they could simulate based on such patterns, different scenarios concerning the potential impact of the trade timing upon their portfolios.

For policymakers and market regulators, the results provide implications in the area of regulation and supervision policies. They should run different dynamic risk assessment processes that could predict and anticipate times of increased risk. Based on such dynamic assessment processes, they should be able to identify the shifts in co-movement and correlation patterns; in other words, they should design and implement “early warning” systems that could identify such patterns in order to avoid periods of market disruptions. They should adopt flexible policies fostering coordination with counterparts at the international level and information sharing. Also, policymakers should consider the good practices implemented within developed stock markets and further adopt them within emerging stock markets (i.e., the BRICS group of financial markets, which are situated at the boundary/frontier of developed and emerging markets).

Financial institutions are also impacted by the interconnectedness of emerging stock markets. Therefore, several implications for their perspective could be identified. They should adapt their strategies for capital management and liquidity by running robust stress testing analysis that could accurately estimate the impact of interconnectedness in different time-horizons.

The limitations within this research are given by the limited dataset, despite the length of the timespan that encompasses two different categories of turmoil periods, namely pre-2019 where the shocks were endogenous or inside the market, and post-2019 where the shocks were of exogenous nature. Also, the analysis of the mechanisms that drive the substitutions in dominance on the short-term (lower timescales), compared to long-term (higher timescales).

The results within this study encourage towards various future research paths. First, the analysis of the substitution mechanisms and effects of market dominance on the long-run compared to short-run. Second, the study of the factors that lead to such variations and frequencies in the evolutive pattern of emerging markets correlations over the timespan. Third, the comparison of these factors and their effects pre-2019 (where the shocks that lead to financial turmoil periods were of endogenous nature), and post-2019 (where the turmoil periods were induced by exogenous shocks).

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