A Wavelet Analysis of Financial Market Performance in Major Markets

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Abstract:

The main objective of this analysis is to show the correlated between China, India, the US and the UK financial markets. A Wavelet Coherence is used to demonstrate the strength of relationships established across the Global Financial Meltdown (GFM) and during the COVID-19 pandemic between selected markets. The date of study varies from August 2000 to June 2020. The study's outcome indicates that the frequency of the relationship between the markets chosen varies. In comparison with China, India's stock market was heavily integrated into developed world markets, especially during the GFM and COVID-19 periods. Related to GFM during the recent COVID-19 recession, the US market continues to dominate the Indian financial markets. Knowing the significance of the relationship established over time between markets gives investors the incentives to cautiously define their diversification of portfolios strategies.

Keywords: *Financial markets, correlated, recession, diversification of portfolios*

JEL Classification: *C58, G01, G11, G15*

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I. Introduction

The integration of stock markets is a common research theme in financial literature. It is a phenomenon in which two or more markets are strongly inter-linked or inter-dependent. With the retrospective, it is prudent to demonstrate that since the markets are interlinked, any event information is automatically pushed up in other markets than separate information and news outlets. As a result, both markets will react equally to the shock in question. As per (Bekaert & Harvey, 1995), when markets are implemented with character, equal projected stock returns will be generated by investment in these markets. Nonetheless, there will be major barriers for portfolio managers to gain from portfolio diversification advantages.

In view of the tremendous economic growth of selected stock markets such as China, India, the United States and the United Kingdom, investors have been given an opportunity to harvest potential returns on investment. Nevertheless, the recurrence of the financial and economic crisis has created fear among investors that their investments in these integrated markets could spread. These countries have maintained a close relation between them over the years with regard to trade, capital flows and other bilateral activities. Therefore, when planning their asset allocation strategies, fund managers are keen to consider the strength of the relationship established over time between these growing markets.

II. Literature Review

Over the past 40 years, comprehensive studies have been carried out to explore the degree of convergence between global capital markets. Research on stock market convergence offers an impetus for global investors to form their strategies for portfolio diversification. It would be important to see that most of the researchers stressed the integration of developed stock markets at the beginning of the 1970s, because developed countries were the powerful economies of the world. For instance (Agmon, 1972), important ties between the stock markets of the United States, the United Kingdom, Germany and Japan were highlighted. At the later stage, however most research studies concentrate on the integration of other markets especially the emerging class, due to its prominent position in the global economy. Some of the notable studies on Asian markets' integration are as follows. An rise in the correlation between daily stock returns from the Asian markets was observed for the period 1990 to 2003 (Chiang, Jeon, & Li, 2007). By using the Wavelet method (Tiwari, Dar, Bhanja, & Shah, 2013), he proposed that Asian markets are more integrated at a lower frequency compared to high frequency. The long-term relationship between some of the Asian emerging markets has also been reported (Palamalai, M., & Devakumar, 2013) and the potential for diversification has therefore declined. (Hussain & Saeed, 2016) have established relations between developed and emerging markets in Asia and within them. One of the recent reports, however, (Das & Manoharan, 2019) revealed a poor form of South Asian market integration. Therefore for portfolio diversification, this sector offers scope. Few researchers have tested the stock market integration around the global financial crisis over a number of years. The relation between some of the major developed markets and Asian

emerging markets has been observed (Wong, Penm, & Terrell, 2004) and has changed since the crash in October 1987. (Wang, 2014) found in their research that while integration between East Asian markets was strengthened by the global financial crisis, these markets are less linked to the shocks originating in the US after the crisis. The mixed outcome of the effect on East Asian stock markets of the Asian and global financial crises (Rizvi & Arshad, 2016) was also listed. The impact and association of US stock markets with Asian markets was also noted in some studies such as (Singh & Singh, 2010) (Sharma, 2011), (Dhanaraj, Gopalaswamy, & M, 2013) (Lingaraja, 2015) (Siddiqui, 2009) noted, however, that the US market had less impact on Asian stock markets. It noted that the strength of integration that has evolved over a number of years on a time scale has not received much attention from the literature on stock market integration. The rising emerging economies of Asia are China and India. On the other hand, in terms of investment, procurement of capital and other bilateral operations, the US and the UK are most closely related to these markets. Therefore the trending relationship between these markets on a time and frequency scale is very important to consider. This would make it easier for investors to define effective strategies for portfolio diversification relevant to those markets.

III. Methodology

The research utilised the regular inventory prices of two developing Asian markets (China and India) and two developed world markets (US and UK). As sample variables, the leading inventory indices such as Nifty 50, SHCOM, S& P 500 and FTSE 100 were used. The research was extended to run from 30 August 2000 until 30 June 2020. In addition to offering a good picture of the stock market relationship, the study period was divided into four sub-periods. (i) Pre-Global Financial Meltdown (Pre- GFM) - 30 August 2000 to 29 August 2008, (ii) Global Financial Crisis (GFM) - 1 September 2008 to 1 May 2009, (iii) Post-Global Financial Meltdown (Post- GFM) - 4 May 2009 to 30 December 2019, and (iv) Crisis period COVID-19 - 31 December to 30 June 2020.

The Johansen Cointegration test (for long-term relationships) or Granger Causality test can be used to see if two or more markets come together once (for short-run relationship). But the question remains about the strength over time spans of relationships. If one wants to verify this, then it is not beneficial to use the above models. The Econometrician therefore established the Wavelet structure to exhibit the strength of association across the time frame and frequency domain. Wavelet-based tests provide details about relationships without losing the dimensions of the time scale, unlike other econometrics models. Similarly, unlike econometrics models, stationarity is not a pre-condition for Wavelet analysis. Therefore, we used the Wavelet Coherence method to demonstrate the significance of the association between China, India, US and UK stock markets over time horizons, taking into account the constraints of the econometrics model. The two-series Wavelet Coherence equation as per the following (Torrence & Compo, 1998);

$$R_n^2(s) = \frac{\left|S\left(s^{-1}W_n^{xy}(s)\right)\right|^2}{S(s^{-1}|W_n^x(s)|^2).S\left(s^{-1}|W_n^y(s)|^2\right)}$$

Where, R^2 and S function as a Wavelet Squared Coherence and a smoothening operator across time scale. However, this equation also resembles the equation of the traditional correlation coefficient. The Wavelet Coherence value ranges between 0-1 (zero represents no correlation and one represents higher correlation).

IV. Analysis and Discussion

Table 1: Descriptive figures on returns from capital markets

Stock Markets	Mean	Standard Deviation	Skewness	Kurtosis
Pre - Global Financial Crisis				
US	-0.0072	1.0872	0.1052	5.4138
UK	0.0030	1.1915	-0.2100	5.6442
China	0.0161	1.5956	-0.1244	7.9962
India	0.0573	1.6139	-0.6871	8.1426
Global Financial Crisis				
US	-0.2213	3.2945	0.0333	4.0632
UK	-0.2694	3.5373	0.2864	5.0193
China	0.0367	2.4553	0.2628	4.2230
India	-0.2023	3.2828	-0.3210	3.9303
Post - Global Financial Crisis				
US	0.0470	0.9350	-0.4532	7.3559
UK	0.0164	1.1271	-0.5064	8.3425
China	0.0053	1.3820	-0.9418	21.9405
India	0.0307	1.3258	0.8558	8.9875
COVID-19 Pandemic				
US	-0.0415	2.8779	-0.6140	7.3881
UK	-0.2092	2.6177	-0.8383	8.9359
China	-0.0281	1.4761	-2.3134	16.2958
India	-0.1748	2.8309	-1.2727	9.56615

Notes: The table provides a description of the stock return figures for the pre-GFM, GFM, post-GFM and COVID-19 eras.

The overview statistics of the returns from the US, UK, China and Indian stock markets are shown in Table 1. All capital markets offer positive returns to investors at an agreed level of risk over the usual period (except for the US in the pre- GFM *period*). For example, the Asian emerging markets (China and India) presented regular return opportunities of 0.0161 percent and 0.0573 percent for a standard deviation of 1.5956 percent and 1.6139 percent during the Pre-GFM *era*. This is better than the economies that have grown. However it is worth remembering that markets have robbed investors during both crisis periods by delivering negative returns (except China market which has shown positive returns during GFM*)*. The highest negative mean returns showed by the UK and Indian markets for a higher level of risk during the COVID-19 era. The Skewness and Kurtosis values reflect the characteristics of the distribution of returns.

Table 2: Capital markets correlation

Stock Markets	Pre - GFC	GFC	Post - GFC	COVID-19
US - China	0.6489	-0.0324	0.2919	0.7650
US – India	0.7560	0.9186	0.8343	0.8642
US – UK	0.9261	0.9833	0.3847	0.8945
UK – China	0.7166	-0.0470	0.0867	0.8244
UK – India	0.9098	0.9143	0.2807	0.9682
China - India	0.8261	0.2732	0.3991	0.8457

Notes: The table strictly indicates the degree of association between the Pre-GFM, GFM, Post-GFM, and COVID- 19 business pairs. The power of correlation has developed over the time shown in Figure 1-4.

Table 2 offers a preliminary insight into the connection between stock market pairs in the US, UK, China and India. The degree of association between markets for the sample period is calculated (Pre-GFM*,* GFM*,* Post- GFM *and* during COVID-19). We noted a strong correlation between selected stock markets over four sample periods (except, during GFM *US*-China and UK-China share negative relationship). For a selected sample period, all market pairs lead to a higher correlation, except that the markets in GFM *China* share a low and negative relationship with developed markets. Similarly, we found a lower US-China and UK-China correlation coefficient during the Post- GFM *era*.

Wavelet Coherence

The Wavelet approach offers a deeper understanding of the correlation between selected stock markets over the time scale and frequency domain, as opposed to the simple correlation process. The Wavelet Coherence between stock market pairs as shown in Figure 4 for the pre-GFM, GFM, post-GFM and current COVID-19 crisis eras. The horizontal axis displays the horizon of time and the vertical axis shows the frequency band (daily time units). The correlation force varies from 0-1. With the color codes displayed on the right-hand side of each plot, the degree of association can be understood. The surface with a blue or cold color in the plot shows a poor type of integration, while red or warmer colors display greater interdependence between markets. Likewise, arrows display the market leading to other (up or down arrows) and the degree of strong negative or positive relationship in a warmer area (left or right arrows).

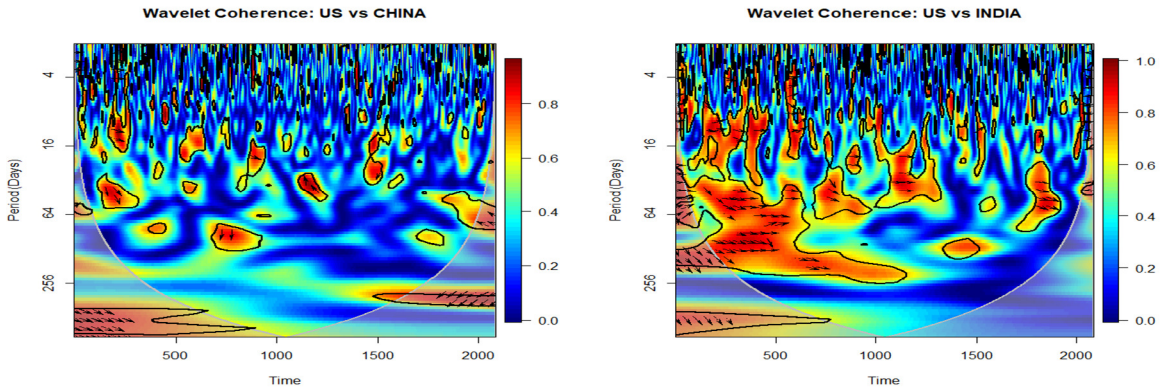
We view how each stock market moves through selected sub-periods with others (Figure 1-4). Starting with China, during the Pre-GFM period, we noted a moderate form of its relationship with the US, the UK and India, which only lasts for a short period of 2-16 days (see dark warmer plots in Figure 1). The China vs. India plot on the time scale of approximately 1200 data observations (August 2002 to end December 2004), leading India in the long run to China's financial markets. Surprisingly, as opposed to Pre-GFM, the reliability of its relationship with other selected markets is weak during the global financial crisis. This can be seen in Figure 2, as the cold color of most of the plot surface was observed. This is a finding worth remembering. However the relationship between China and other selected markets has developed significantly

in the post-GFM era. This has been illustrated with a warmer color on the plot surface and this relationship continues for a scale of 2-64 days. There is however a lower lead-lag relationship between the markets. In the recent COVID-19 period, if we notice the strength of China's market relationship with others, this is higher, particularly for the period from February 2020 to March 2020. As of 31 December 2020, this crisis emerged in China. Therefore in this era, we also observed signs of greater dominance over China by the US, UK and Indian stock markets.

See (Figure 1-4) the relationship between the Indian stock market and the US and UK. It shares a close relationship with developed world markets over the Pre-GFC period. These markets move together on a scale of > 64 days, with most of the arrows shifting to the right in the warmer zone. This suggests that the markets have a strong connection. Indian stock markets were jolted by the occurrence of GFC, unlike China. It displayed strong ties with developed markets, especially the US, via daily time units during crisis times. The plot structure also illustrates the dominant position of the US over the Indian stock market. We also noted strong changes in the Indian stock market with developed markets on a time scale from Figure 3, but they are short-run dynamics. However the United States and the United Kingdom did not play a dominant role in India during this time. The relationship between these markets also increased during the COVID-19 era, but the strength of the relationship began to expand dramatically only 30 days after the beginning of the crisis (from February 2020). With upward arrows in a warmer region, during the crisis era, the US continues to play a dominant role over India. However in the case of India, we have seen an inverse effect on the UK stock market during the COVID-19 era.

With respect to the effects between established stock markets in the US and the UK, we noted that both markets are moving together over four sub-sample periods. However the ties between the GFM and COVID-19 markets were noted to be significantly higher during the time. The arrows also show the lead-lag relationship between markets in a warmer area. However the unusual finding that the US market had a greater effect on UK markets during the COVID-19 era was noticeable.

A. Pre – Global Financial Meltdown



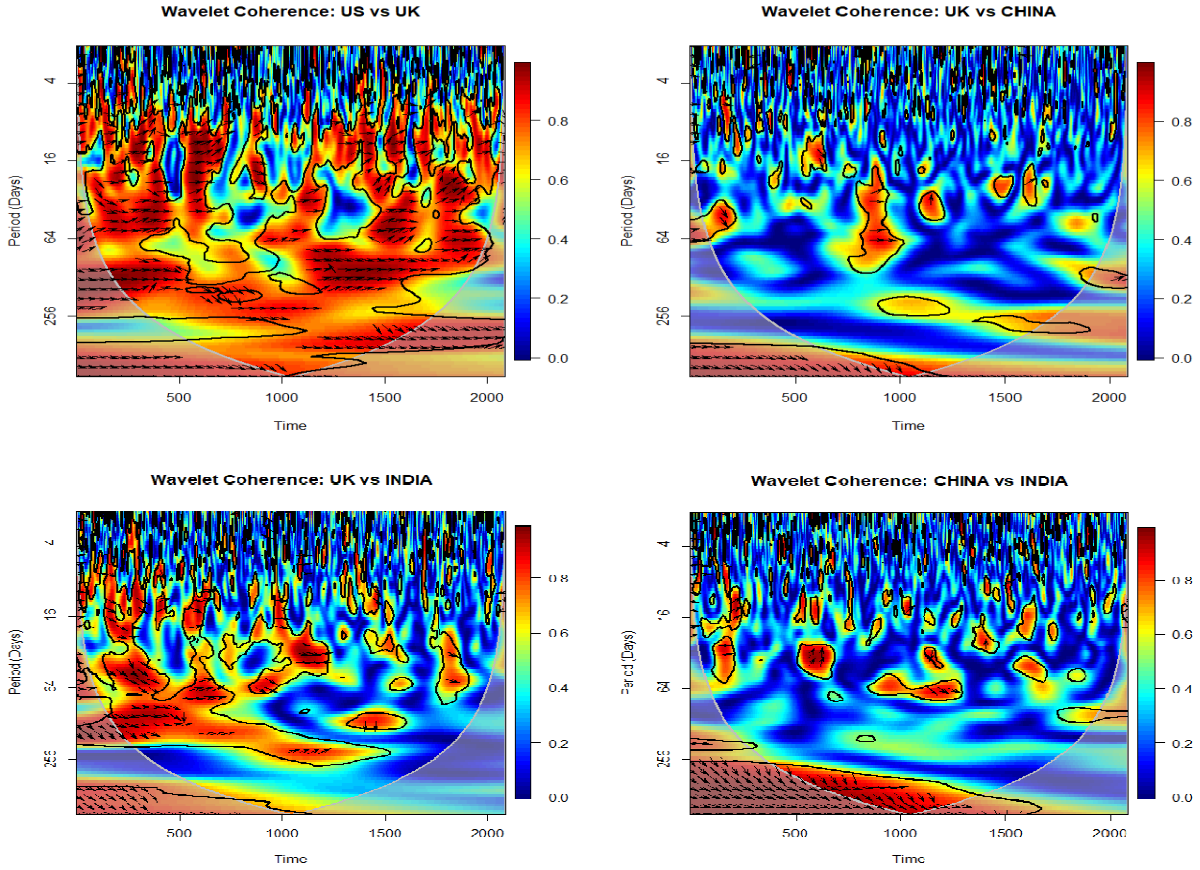
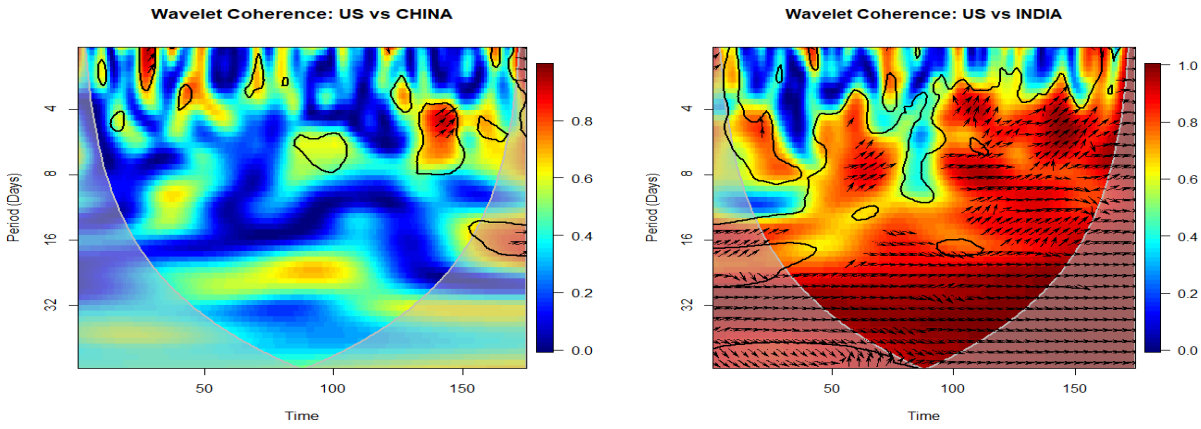


Figure 1: *Wavelet Coherence of pairs of stock markets between the US, UK, China and India. The vertical axis indicates intervals (days) and the time scale is defined by the horizontal axis (Pre - Global financial Meltdown time period). The warmer the color of the surface of the plot, the greater the distribution between stock markets. A lower degree of interdependence is reflected by the cold region in the plot.*

B. Global Financial Meltdown



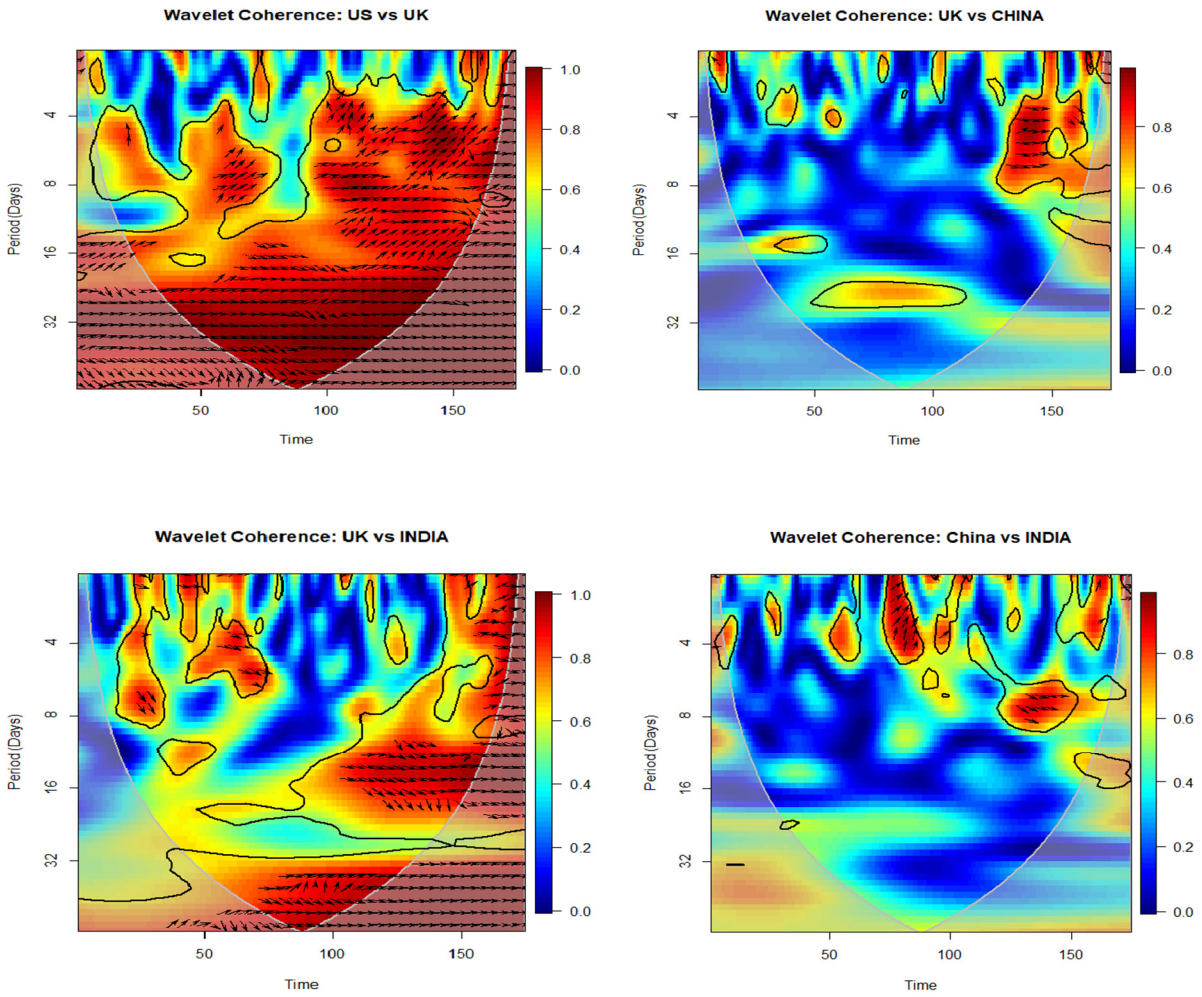
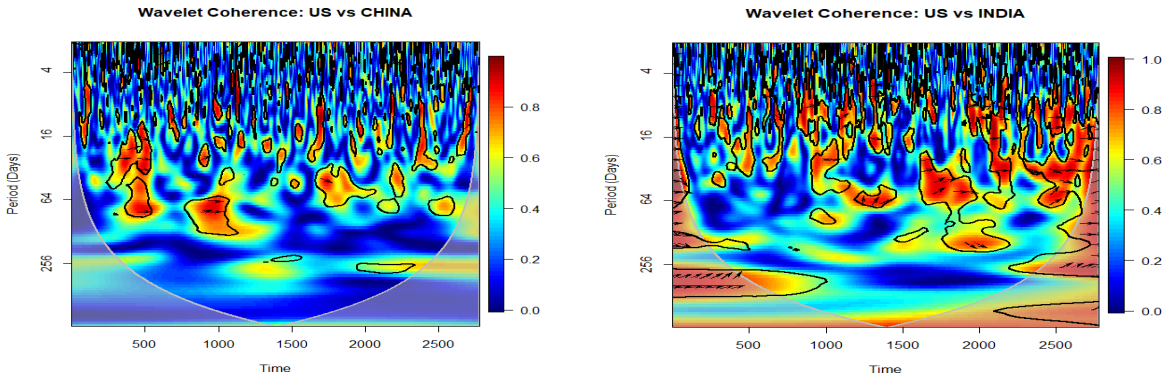


Figure 2: *Wavelet Coherence of pairs of stock markets between the US, UK, China and India. The vertical axis indicates intervals (days) and the time scale is defined by the horizontal axis (Global financial crisis time period). The warmer the color of the surface of the plot, the greater the distribution between stock markets. A lower degree of interdependence is the cold area in the story.*

C. Post – Global Financial Meltdown



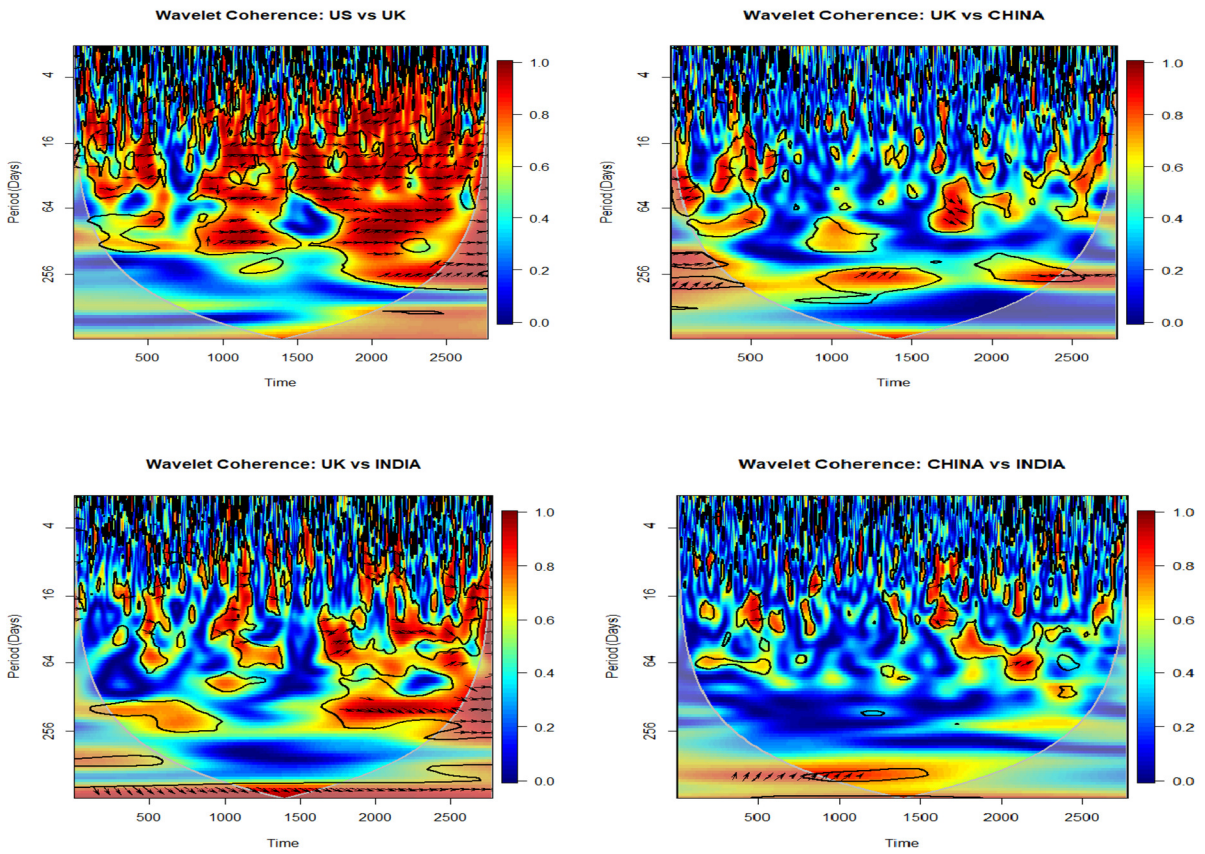
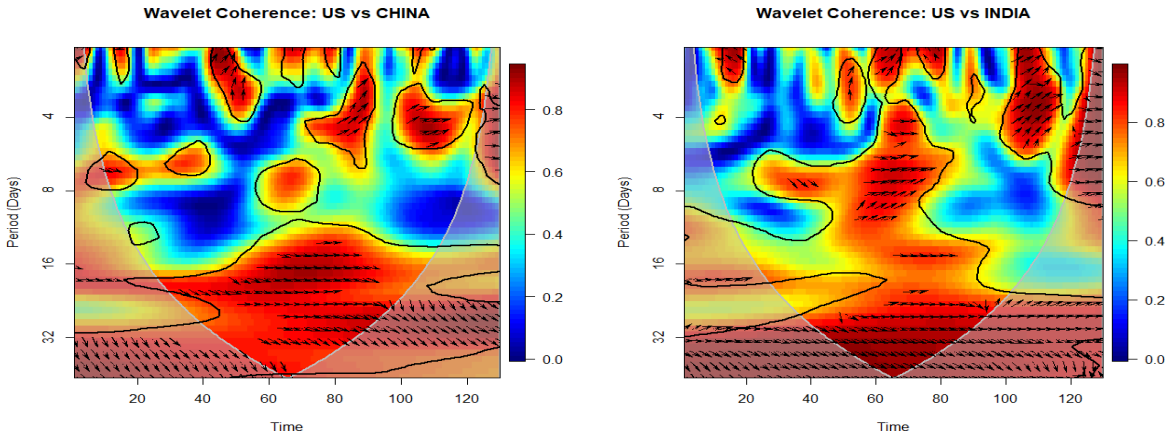


Figure 3: *Wavelet Coherence of pairs of stock markets from the US, UK, China and India. The vertical axis indicates the length (days) and the time scale is defined by the horizontal axis (Post - Global financial crisis time period). The colder the color of the surface of the plot, the higher the distribution between stock markets. The colder area in the plot indicates a lower level of interdependence.*

D. COVID-19



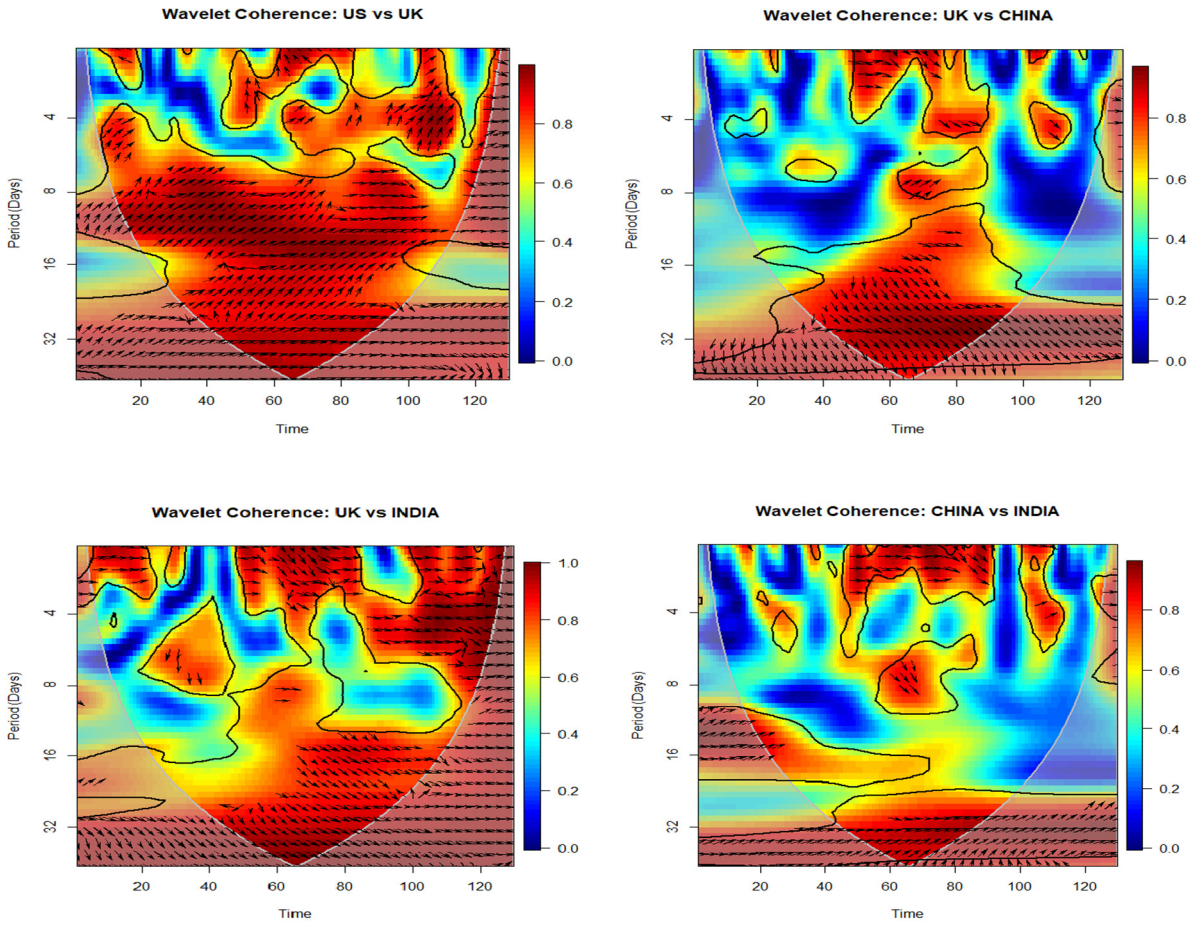


Figure 4: *Wavelet Coherence of US, UK, China and India stock markets pairs. The vertical axis exhibits period (days) and the horizontal axis represents the time scale (COVID-19 crisis time period). The warmer the color in the plot surface, the higher comovement between stock markets. The cold region in the plot represents a lower degree of interdependency.*

V. Conclusion

Owing to the high degree of interdependence or interconnectivity, fund managers and other investors have built obstacles to diversifying their portfolios throughout markets. This study looks at the convergence of two developing Asian stock markets (China and India) with two established markets (US and UK) in the context of the global financial crisis and the recent COVID-19 crisis. The Wavelet Coherence system has been used to explain the development across the time-scale and frequency domain of the relationship between selected stock markets. The effect of the Wavelet Coherence indicates that during Pre-GFM, GFM and Post-GFM, China Stock markets show the poor sign of convergence with other chosen markets, but it has impacted due to the crisis emanating from its home town. Therefore when planning their portfolio diversification plans, investors should take note of this. For four sample periods, especially during the GFM and COVID-19 crisis, the strength of the relationship between the Indian and developed markets was significantly higher. We also noticed the strong dominance of the US market over Indian stock markets during the

COVID-19 era, similar to the GFM period. On the other hand, during the COVID-19 era, the Indian stock market showed signs of influence over the UK markets. Therefore the strength of the market-to-market relationship indicates a decline in the reach of portfolio diversification in Indian stock markets, particularly during the crisis. In line with the results of the study (Singh & Singh, 2010), the effect of the US on the Indian stock market was also suggested (Lingaraja, 2015); the correlation of China and Indian stock markets with the US and UK markets was recorded. The report also explains the close connections across sample periods between the US and UK markets. However, recognizing the importance of the relationship built between the markets gives investors incentives to cautiously work out their strategies for portfolio diversification.

VI. References

Agmon, T. (1972). The Relations Among Equity Markets: A Study of Share Price Co-Movements in the United States, United Kingdom, Germany and Japan. *The Journal of Finance, 27* (4), 839-855.

Bekaert, G., & Harvey, C. R. (1995). Time-Varying World Market Integration. *The Journal of Finance, 50* (2), 403-444.

Chiang, T. C., Jeon, B. N., & Li, H. (2007). Dynamic correlation analysis of financial contagion: Evidence from Asian markets. *Journal of International Money and Finance, 26*, 1206-1228.

Das, D., & Manoharan, K. (2019). Emerging stock market co-movements in South Asia: wavelet approach. *International Journal of Managerial Finance, 15* (2), 236-256.

Dhanaraj, S., Gopalaswamy, A. K., & M, S. B. (2013). Dynamic interdependence between US and Asian markets: an empirical study. *Journal of Financial Economic Policy, 5* (2), 220-237.

Hussain, A., & Saeed, T. (2016). Cointegration of stock market returns: A case of Asian countries. *Pakistan Journal of Applied Economics, 26* (2), 153-181.

Lingaraja, K. (2015). Long-run dynamic linkages between emerging stock markets in Asia and a developed stock markets (DJIA). *Research Journal of Applied Sciences, 10* (5), 203-211.

Palamalai, S., M., K., & Devakumar, C. (2013). Stock Market Linkages in Emerging Asia-Pacific Markets. *SAGE Open*, 1-15.

Rizvi, S. A., & Arshad, S. (2016). How does crisis affect efficiency? An empirical study of East Asian markets. *Borsa Istanbul Review, 16* (1), 1-8.

Sharma, P. (2011). Asian Emerging Economies and United States of America: Do they offer a Diversification benefit? *Australian Journal of Business and Management Research, 1* (4), 85-92.

Siddiqui, S. (2009). Stock Markets Integration: Examining dynamic linkages between select Asian and US markets. *Vision - The Journal of Business Perspective, 13* (1), 19-30.

Singh, G., & Singh, P. (2010). Chinese and Indian Stock Market Linkages with Developed Stock Markets. *Asian Journal of Finance & Accounting, 2* (2), 21-39.

Tiwari, A. K., Dar, A. B., Bhanja, N., & Shah, A. (2013). Stock Market Integration in Asian Countries: evidence from Wavelet multiple correlations. *Journal of Economic Integration, 28* (3), 441-456.

Torrence, C., & Compo, G. P. (1998). A Practical Guide to Wavelet Analysis. *Bulletin American Meteorological Society, 79* (1), 61-78.

Wang, L. (2014). Who moves East Asian stock markets? The role of the 2007–2009 global financial crisis. *International Financial Markets, Institutions and Money, 28*, 182-203.

Wong, W. K., Penm, J., & Terrell, R. D. (2004). The Relationship Between Stock Markets of Major Developed Countries and Asian Emerging Markets. *Journal of Applied Mathematics and Decision Sciences, 8* (4), 201-218.