Financial Contagion in the Recent Financial Crisis: Evidence from the Romanian Capital Market

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Abstract

We use the wavelet analysis in order to investigate if financial contagion occurred between the US and the Romanian capital market in the beginning of the recent economic crisis. Moreover, we test presence of pure and fundamental contagion between the two markets using wavelet coherency analysis and maximal overlap discrete wavelet transform methodology. We find evidence of pure financial contagion between the two markets: during the sub-primes crisis period, the Lehman Brothers collapse and at the beginning of sovereign debt crisis. Furthermore, we find a general short-term increase in interdependence between the two markets in the ex-ante and ex-post Lehman brothers period. Meanwhile, the capital market from Romania and US were in perfect sync during 2007-2009 for high trading time-windows. This implies that the Romanian market was sensitive to short-term shock from the US market, which lead to a long-term fundamental contagion.

Key words: financial contagion, capital markets, financial crisis, wavelet analysis
J.E.L. classification: M42, M48, H83

1. Introduction

In the outbreak of the 2008 financial crisis, understanding stock markets' comovement and financial contagion mechanism has become a key focus of investors and risk managers, but also for national and international financial authorities. While investors and risk managers seek out a reduction in the risk associated with their portfolio by investing in different countries, national and international financial authorities need to take actions in order to protect the financial stability of a country or the international financial system. Therefore, most of the studies regarding financial markets comovement reveal the potential benefits of international portfolio diversification as measure of managing risks in an integrated global financial market. However, in period of crisis the true benefits of international diversification tend to diminish or even vanish, as investors tend to behave irrationally in an environment where financial contagion is present.

In the context of the recent financial crisis, there is an increasing interest towards understating the main factors that contribute to fundamental and pure based contagion. While, pure based contagion evolves around short-term shock in the financial markets (Forbes and Rigobon 2002) or long-term financial contagion due to macroeconomic factors. The recent financial crisis has brought into light the importance short-term contagion as it is the main factor that is responsible for speeding the crisis on a global scale. Many studies, like (Syllignakis and Kouretas 2011; Gallegati 2012; Kiviaho et al., 2014; Dewandaru et al., 2016) have emphasized the detrimental effect of shocks that originated from the US on the global financial scale. There is clear evidence of pure contagion between the US market and most developed capital markets (Gallegati 2012), from the US towards emerging markets (Kiviaho et al., 2014), or even between countries members of the European Union (Dewandaru et al., 2016).

Nevertheless, few studies try to emphasize the implications of the recent financial crisis that debuted with the Lehman Brothers bankruptcy on the Romanian capital market. Furthermore, fewer studies use a modern method of analyzing financial contagion: the wavelet methodology, which has several advantages compared to traditional methods of testing financial contagion. One of the major advantages of the wavelet methodology involves around the ability to analyze at the same time both time and frequency domains, distinguishing pure contagion from fundamental contagion.

Therefore, the aim of this paper is to investigate if the Romanian capital market experienced pure financial contagion from the US capital market in the outbreak of the recent financial crisis. The rest of this paper is organized as follows: section 2 presents the data use in the analysis, section 3 presents the methodology, section 4 presents the empirical results while section 5 concludes.

2. Data

The aim of our paper is to test whether the Romanian capital market exhibited a contagion phenomenon in relation to the US capital market after the Lehman Brother collapse in 14 September 2008. In our analysis, we use the *BET* – index as a proxy for the Romanian capital market and the *S&P 500* index as a proxy for the US capital market. In order to capture the effect of the contagion phenomenon we will split our data in an ex-ante and ex-post periods, which consist of 256 trading days similar to (Dewandaru et al., 2016). In addition, in order to prevent the *non-synchronous trading effect* we will eliminate all non-trading days, legal holydays in each of these two countries. Therefore, our analysis period spans from 27 August 2007 – 2 October 2010. Furthermore, similar to (Gallegati 2012) we will align the daily *t* returns of the Romanian capital market with daily returns of the US market from the previous day *t-1* in order ensure that information from the US market is contemporaneous with data from the Romanian capital market.

The source of data is DataStream and it represent the stock market indices are transformed into daily returns by calculating the logarithmic differences of the daily end prices as in $r_t = ln\ (P_t/P_{t-1})$, where P_t and P_{t-1} represent the stock price index at time *t* and *t-1*, respectively. We use local currencies for each country to calculate the raw indices as in previous studies like (Kiviaho et al. 2014) because Mink (2015) argues that only local currency captures the true effect of contagion. Table no 1 contains the descriptive statistics for all the data, including the two sub samples. The first sample contains data from 27 August 2007 until the Lehman Brothers collapse in 14 September 2008, while the second samples contain data from 15 September 2008 - 2 October 2010.

Table no. 1 Descriptive statistics

	BET1	BET2	BET	SP500-1	SP500-2	SP500
Mean	-0.002434	-0.000616	-0.001529	-0.000592	-0.000534	-0.000563
Median	-0.001803	0.000222	-0.000696	0.000244	0.000977	0.000381
Maximum	0.046109	0.100907	0.100907	0.041535	0.109572	0.109572
Minimum	-0.075649	-0.131168	-0.131168	-0.034734	-0.094695	-0.094695
Std. Dev.	0.018470	0.032120	0.026163	0.013298	0.027407	0.021520
Skewness	-0.275359	-0.445200	-0.404968	-0.014015	0.042239	0.044365
Kurtosis	3.762600	4.698128	5.717925	3.304523	5.254212	7.125197
Jarque-Bera	9.327788	38.44956	168.9053	0.997544	54.27850	363.2027
Probability	0.009430	0.000000	0.000000	0.607276	0.000000	0.000000
Observations	252	252	512	256	256	512

Source: Own computations by the authors on data provided by Datastream

3. Methodology

One of the most important contribution of our study evolves around using the wavelet analysis in order to test for the presence of financial contagion. We will use the methodology developed by Gallegati (2012) in order to test in a visual manner the presence of contagion.

3.1 Multiscale Analysis of Correlation

The multiscale analysis of correlation is a specific method of analysis in the wavelet methodology that uses the individual variance between two variables at a certain scale to test the presence of market contagion.

By computing the wavelet variance at scale j, $\sigma_X^2\left(\lambda_j\right)$ of a distinct stationary stochastic process $\{X\}$, with the variance of *j-level* wavelet coefficient and time *t*, we can compute wavelet coefficients from the MODWT (Maximal Overlap Discrete Wavelet Transform) filter as in formula (1):

$$\sigma_X^2\left(\lambda_j\right) = Var\left(\omega_{j,t}^X\right) \quad (1)$$

Furthermore, we can compute covariance between two process X and Y within the wavelet framework, but in scale dependent manor as in formula (2):

$$\gamma_{XY}\left(\lambda_j\right) = Cov\left(\omega_{j,t}^X \omega_{j,t}^Y\right) \quad (2)$$

Where $\omega_{j,t}^X$ – is the stochastic process obtained by filtering the X_t series with the MODWT filter.

In addition, we can compute wavelet correlation coefficient between two variables $\rho_{XY}\left(\lambda_j\right)$ with the help of a unbiased estimators $\tilde{\sigma}_X\left(\lambda_j\right)$, $\tilde{\sigma}_Y\left(\lambda_j\right)$, and the scale dependent covariance $\tilde{\gamma}_{XY}\left(\lambda_j\right)$ as in formula (3):

$$\tilde{\rho}_{XY}\left(\lambda_j\right) = \frac{\tilde{\gamma}_{XY}\left(\lambda_j\right)}{\tilde{\sigma}_X\left(\lambda_j\right)\tilde{\sigma}_Y\left(\lambda_j\right)} \quad (3)$$

Following the indications of methodology employed by Gallegati (2012), we use the wavelet methodology in order to test for the presence of market contagion with the help of the confidence intervals of each individual estimator of the wavelet correlation for scale *j*, $\tilde{\rho}_{XY}\left(\lambda_j\right)$. This involves plotting the wavelet cross-correlation coefficients at each scale of analysis alongside the upper and lower confidence interval for the coefficients. If there is evidence of market contagion, we will notice a shift downwards or upwards in the estimation of the wavelet coefficients of the two distinct periods of analysis. By plotting the random interval that forms 100*(1-2*p*) % confidence interval, from the robust estimator MODWT we check if any of the confidence intervals are non-overlapping in order to detect market contagion. This involves plotting the estimated wavelet correlation coefficients for the ex-ante and the ex-post periods as $\tilde{\rho}_{xy}^{I}\left(\lambda_j\right)$ and $\tilde{\rho}_{xy}^{II}\left(\lambda_j\right)$, respectively, and then issuing the null hypothesis of no market contagion as in Gallegati (2012) and in formula (4):

$$H_0\colon \tilde{\rho}_{xy}^{I}\left(\lambda_j\right) = \tilde{\rho}_{xy}^{II}\left(\lambda_j\right) \quad (4)$$

If any point of wavelet scale of the graph, the two confidence intervals are non-overlapping the null hypothesis of no-contagion is rejected and we accept the presence of market contagion at that scale, between the two markets. Consequently, if the wavelet confidence are overlapping we reject the presence of contagion between the two markets at a certain scale.

In estimating, the MODTW coefficients we will use the Daubechies compactly supported least asymmetric (LA) wavelet filter (Daubechies 1992) of length *L = 8*, noted by LA (8) for determining the $\tilde{\rho}_{XY}\left(\lambda_j\right)$ on a scale-by-scale basis. We prefer to use this wavelet filter, because previous studies like (Gallegati 2012) have indicated that this filter is most adequate to handle high frequency data such as time series data.

3.2 The Continuous Wavelet Transform

The continuous wavelet transform (CWT), initially developed by Torrence and Compo (1998) allows testing synchronization and delays between two time series. The CWT $W_n^X(s)$ of an individual time series x_n with a scale *s* is obtained by projecting a mother wavelet ψ_0 on the existing series. If we use in the analysis the Morlet wavelet, the CWT becomes:

$$W_n^X(s) = \sqrt{\frac{\delta t}{s}} \sum_{n'=1}^{N} x_{n'} \psi_0\left((n'-n)\frac{\delta t}{s}\right), \quad n' = 1,2,\dots,N \quad (5)$$

3.3 Wavelet coherence

The wavelet coherence analysis is a method that allows testing the interactions between two time series variables series X and Y. This involves comparing the cross-wavelet spectrum to the product of the spectrum of each individual series, which allows us to compare the interaction of the two variables in both time and the frequency domain. Torrence and Webster (1998) and Grinsted et al. (2004) argue that wavelet coherence between two variables $R_n^2(s)$ can be calculated as in formula (6):

$$R_n^2(s) = \frac{\left|S\left(s^{-1}W_n^{XY}(s)\right)\right|^2}{S(s^{-1}|W_n^X(s)|^2).S(s^{-1}|W_n^Y(s)|^2)} \quad (6)$$

where: $W_n^X(s)$ and $W_n^Y(s)$ are the wavelet transforms (WTC) of two time series, S(.) is the smoothing operator and *s* is the wavelet scale.

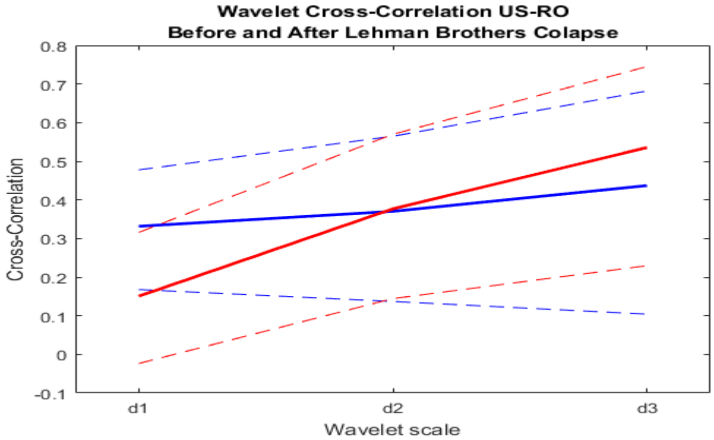
When testing market contagion, we interpret high values of coherence coefficients as high degrees of interactions between two variables. Furthermore, if the coherency coefficients are in the lower scale we interpret them as "pure" contagion, while high values for the coefficients in the high values can be attributed to the "fundamentals".

4. Empirical results

One of the major contribution of our analysis is the use of wavelet methodology in testing market contagion. Thus we test whether the Romanian capital market exhibited market contagion from the main driver of the recent financial crisis the US capital market.

Our results from figure no. 1 reveal some intrigued results. On a general note, we find that on average the wavelet coefficients for the second analysis period 15 September 2009 until 2 October 2010 are higher than the coefficients before the Lehman Brothers collapse 27 August 2007 - 14 September 2008. This increase in wavelet cross-correlation coefficients is expected, as in a period of crisis, the degree of interdependence between markets is higher. However, the increase in wavelet coefficients is not high enough to mark an actually contagion effect. Our results reveal that the confidence intervals are overlapping at all the scales, thus we accept the null hypothesis of no market contagion between the Romanian Capital market and the US market in the aftermath of the Lehman Brothers collapse.

Figure no. 1. Wavelet Cross-Correlations US-RO before and after Lehman Brothers Collapse



Source: Own computations by the author on data provided by Datastream

Note: Estimated wavelet correlation of US and RO countries stock market returns for before the Lehman Brothers collapse (blue line) and after the collapse (red line) periods. The dashed lines denote the upper and lower bounds for the 95 percent confidence interval before (blue dashed line) and after (red dashed line) Lehman. The null hypothesis of no contagion is rejected when the confidence intervals are not overlapping.

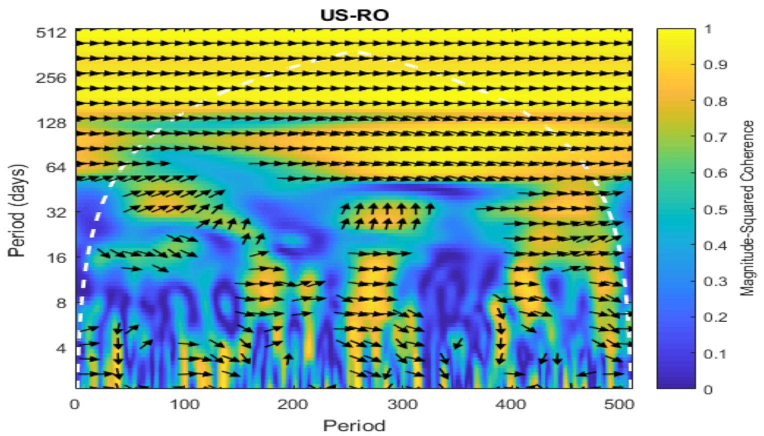
The changes in wavelet cross-correlation coefficients indicate a gradual increase in the degree of interdependence between the US and Romanian capital market, but the changes aren't significant enough to argues that only the Lemon Brothers collapse was the sole factor. Either way our results could indicate that the Romanian capital market wasn't affected by the Lehman Brother collapse, or there were more than one period of pure market contagion in our analysis period 27 August 2007 – 2 October 2010. We also note that the BET index was in a downwards trend in 2007-2008 long before the Lehman Brother collapse. In the same period, the US market proxied by the S&P 500 index suffered less severe losses. Nevertheless, we can conclude that the Romanian market reacted to the impulses from the US capital market in the aftermath of the Lehman Brother collapse, but there is no clear evidence of market contagion solely in this period.

Figure no. 2 represent additional testing for our initial results. We use a coherency analysis in order two validate our initial results and assumptions. One major advantage of the wavelet coherency analysis is the ability to plot simultaneously the frequency data and the time date. Thus, we can interpret on the vertical axis the frequency domain and in the horizontal axis the time domain. By using the coherency analysis, we can see not only periods of market contagion, but we can also pinpoint exactly the moments in time when they occurred.

In our analysis, we use a range of colors that varies from light blue (low coherency values) to yellow (high coherency values) in order to test the interdependence and contagion phenomenon on a scale-by-scale basis. Our results from the wavelet coherency analysis indicates the signs of market contagion around the date of the Lehman Brothers collapse in 14 September 2008, as we find high areas of yellow in the lower bands 1-8 trading days around the 250 days trading period (Lehman collapse is day 252). In addition, we find that were also additional periods of contagion at the beginning of our analysis period in August - September 2007 and later on, at the start of the year 2008, or 2009. This indicates numerous moments of market contagion that relate to certain other external shocks such as the subprime crisis in the late 2007 and the beginning of 2008 or the sovereign debt crisis that started in the beginning of 2009. This validates our initial results, because we find periods of short-term market contagion before the Lehman Brothers collapse, while the periods are still present latter on during the year 2009.

One of the benefits of the wavelet coherency analysis is that ability to distinguish between „pure" and „fundamental" contagion as figure no. 2 reveals. We find that in the short time window there are clear signs of pure contagion in the 1-8 days trading period and we find also clear evidence of fundamental based contagion in 128-512 trading days, where the US and Romanian capital markets were in almost perfect sync between 2007-2009.

Figure no. 2. Results of the wavelet coherence methodology for US vs. RO



Source: Own computations by the author on data provided by Datastream

Overall, our results from the MODTW analysis indicated that there were numerous periods of market contagion between the US and Romanian capital market, while the results from the coherency analysis validated our initial assumption pinpointing three different periods of contagion. We found clear evidence or market contagion during the subprime crisis, during the Lehman Brothers collapse and at the beginning of the sovereign debt crisis. In the end, our estimates are in line with the results of (Syllignakis and Kouretas 2011) who found market contagion between the US and Romanian capital market during the recent economic crisis based upon a GARCH model. Similarly, (Kiviaho et al. 2014) found evidence of market contagion based upon wavelet coherency analysis on weakly returns.

5. Conclusions

In this study, we analyse whether the Lehman Brothers collapse in the year 2009 marked a contagion period in the Romanian capital market. We use the wavelet analysis in order to test whether, the Lehman Brother collapse was the sole period of market shock or if we can identify other significant periods. There are two important conclusions from our analysis. Firstly, we find that in the aftermath of the Lehman Brother collapse the degree of interdependence between the US and Romanian capital market increased, indicating potential signs of pure contagion. This increase, in market interlinkages poses a real threat to investors as these marks a reduction in the efficiency of international portfolio diversifications. Furthermore, the second conclusion of our study is that Romanian capital market was affected by pure contagion, not only in the aftermath of the Lehman Brothers collapse, but also in the aftermath of the sub-prime crisis in 2007 or at the beginning of the sovereign debt crisis in 2009. The presence of multiple periods of pure contagion pose a real threat to the Romanian national authorities as they need to take the adequate measure in order to protect the local capital market from external shocks.

Despite the abundant literature regarding pure and fundamental based contagion, the lack of an efficient mechanism of protection national capital markets from external shocks poses a real threat to national authorities. Therefore, national authorities need to monitor closely the evolution of interlinkages between international financial markets in order to take adequate measure to isolate the local capital markets from external shocks. An adequate, monetary policy and modern regulation could ensure a higher degree of protection for the national capital markets.

6. References

- Daubechies, I., 1992. Ten Lectures on Wavelets. *CBSM-NSF Regional Conference Series in Applied Mathematics*, SIAM, Philadelphia.
- Dewandaru, G., R. Masih, A. M., Masih., M., 2016. What can wavelets unveil about the vulnerabilities of monetary integration? A tale of Eurozone stock markets. *Economic Modelling* 52B, pp. 981-996.
- Forbes, K. J, Rigobon, R. 2002. No contagion, only interdependence: Measuring stock market comovements. *Journal of Finance* 57, no. 5, pp. 2223–2261.
- Gallegati, M., 2012. A wavelet-based approach to test for financial market contagion. *Computational Statistics & Data Analysis* 56, no. 11, pp. 3491–3497.
- Grinsted, A., J. C. Moore, Jevrejeva.*S.*, 2004. Application of the cross wavelet transform and wavelet coherence to geophysical time series. *Nonlinear Processes in Geophysics* 11, no. 5/6 , pp. 561–566.
- Kiviaho, J., J. Nikkinen, V. Piljak, Rothovius. T., 2014. The comovement dynamics of European frontier stock markets. *European Financial Management* 20, no. 3, pp. 574–595.
- Mink, M., 2015. Measuring stock market contagion: Local or common currency returns? Emerging *Markets Review* 22, pp. 18-24.
- Syllignakis, M.N., Kouretas. G.P., 2011, Dynamic correlation analysis of financial contagion: evidence from the central and eastern European markets. *International Review of Economics and Finance* 20, no. 4, pp. 717–732.
- Torrence, C., Compo. G.P., 1998. A Practical Guide to Wavelet Analysis. *Bulletin of American Meteorological Society* 79, no., pp. 61–78
- Torrence, C., Webster. P. J., 1998. The annual cycle of persistence in the El Nino-Southern Oscillation. *Quarterly Journal of the Royal Meteorological Society* 124, no. 550