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CONDITIONAL CORRELATION COEFFICIENT AS A TOOL FOR ANALYSIS OF CONTAGION IN FINANCIAL MARKETS AND REAL ECONOMY INDEXES BASED ON THE SYNTHETIC RATIO

Abstract. *We define contagion in financial markets as a significant increase in cross-market linkages after a shock to one or group of countries. Contagion occurs if cross-market co-movement increases significantly after the shock.*
The main goal of this paper is to analyze changes in dependence between a chosen world stock market and the constructed synthetic index. Subsequently the research hypothesis will be verified: dependence between the synthetic stock market index and other stock markets is increasing in periods of a rapid decrease in value of stock market indexes. Positive verification of this hypothesis means that there is a contagion in financial markets.
***Key words**: contagion in financial markets, synthetic measurement, conditional measure of concordance.*

JEL Classification : C43, C58, G100

1. Introduction

Financial crises are an important phenomenon for the economy because in time of the crisis the cost of intermediation and the cost of credit increases, access to credit is also more difficult. This results in a reduction in activity of the real sector which may lead to the crisis in this sector.

The quite high incidence of financial crises may lead to the conclusion that the financial sector is particularly sensitive to various types of disturbances. In particular, the crisis of recent years has shown how the global economy is sensitive to disturbances in the era of globalization (BIS, 2009; Brunnermeier, 2009; Coffee, 2009; Guillen, 2009; Kolb 2010; Shiller, 2008). For the purposes of examination of determinants of the spread of the financial crisis, one of the methods to analyze the linkages between global capital markets was used in this paper. They should give an answer to the question whether the crisis is a significant increase in the relationship between markets, which in part explains this rapid spread of the crisis.

In literature on contagion most of authors analyses relationship between stock market indices (e.g. see Baig and Goldfajn, 1999; Forbes and Rigobon, 2002; Bae et al., 2003; Baur and Schulze, 2005; Bekaert et al., 2005; Boyer et al., 2006; Chandar et al., 2009; Horta et al. 2010; Markwat et al., 2009 and Dungey et al., 2010 among others). Baur (2012) analyses connection between stock and real markets but he used data only from financial markets, divided on sectors. In our paper we analyse dependence between financial market and real market based on economy indices and stock markets data. We also build synthetic measure based on own economic and stock market data.

A tendency to increase the relationship between financial markets during the crisis, compared with dependency beyond the crisis was one of the phenomena associated with financial crises that have occurred over the past several years. As already mentioned, this property is called financial contagion and because of its fairly serious effects it drew the attention of many theorists and practitioners dealing with finance. Several methods to check the contagion were proposed. Most of these methods focus on finding changes in a multi-dimensional distribution of the return rates in times of crisis and beyond these periods. The basics of this approach and further literature on the subject are presented in papers (Forbes and Rigobon, 2002; Bae et al., 2003; Pericoli and Sbracia, 2003; Dungey et al., 2005; Rodrýguez 2007).

Another approach was introduced a few years ago in papers of (Bradley and Taqqu, 2004; 2005a; 2005b]. The authors have assumed that market contagion from market X to market Y occurs when the dependence between the market X and Y is greater when the market X is in period of above-average declines than when the market situation X is normal. In other words the dependence is greater when the market X returns are in the left tail of the distribution than in its central part. Since this definition does not focus on the period in which there is a crisis, but the manner in which "place" of distribution we are, contagion defined in this manner is called spatial contagion.

Most often, it is assumed that the contagion in financial markets occurs when in the crisis period correlation between price movements in various financial markets is much greater. In this article, the authors attempt to answer the question whether the selected world stock exchanges and economies are infecting each other within the meaning of the definition provided. Conditional copula functions and conditional Spearman's correlation coefficient will be used as a tool.

Construction of a synthetic index of world financial markets is introduced. This index is based on the taxonomic distances of chosen stock market from the “best” object, where the best means object which has highest financial parameters.

Main goal of this paper is to analyze changes in dependence between US stock market (S&P500) and chosen groups of world stock markets and constructed real economy index. The problem of the rising dependence between the markets in the periods of financial turmoil is already very well-known, proved in many empirical studies and with the application of several econometric methods (multivariate GARCH models, Dynamic Conditional Correlation models, copula-based models (see Marçal, et all 2008; Naoui, et all 2010; Lim 2013)). Our study differs in the way we model the "real" economy using a set of three macro series (index of production, unemployment and inflation). Similar type of analysis was conducted by Bloom (2009) who show the effect on financial market volatility on economic growth. We analyze relationship between real economy and financial markets and lag of reaction of the real economy to the stock markets.

2. The methodology of empirical research

The definition of the copula function is as follows: *2*-dimensional function *C*: $[0, 1]^2 \rightarrow [0, 1]$ is referred to as the copula function if it meets the following conditions (Joe, 1997; Nelsen, 2006):

a) $C(u, v)$ is an increasing function regarding *u* and *v*,

b) $C(u, 0) = 0$, $C(0, v) = 0$,

c) $C(u, 1) = u$, $C(1, v) = v$.

The importance of the copula function in the multivariate analysis stems from Sklar's theorem (Sklar, 1959; Schweizer and Sklar, 1974):

Let *H* be the two-dimensional cumulative distribution function whose marginal distributions are respectively denoted by *F* and *G*. Then there is a relationship *C* where:

$$H(u, v) = C(F(u), F(v)). \tag{1}$$

If the *F* and *G* are continuous, then *C* is uniquely determined. In addition, if *F*and *G* constitute cumulative distribution functions, the function *H* defined by the above equation is the two-dimensional cumulative distribution.

In other words, this function gives the full dependence structure between the marginal cumulative distributions, creating along with these distributions a multidimensional one, of course subject to the assumptions set forth above.

Let $C_{(U,V)|S}(u,v)$ be a two-dimensional conditional copula function, conditioned on a subset *S* of the set $[0, 1] \times [0, 1]$ where *U* and *V* are cumulative distributions of returns of two stock market indexes: $U = F(X)$, $V = G(Y)$. *X* is distributions of returns of first stock market index, *Y* – of the second market. In the remaining part of the paper *X* and *Y* will also mean the first and the second market.

To explore the concept of contagion, we can consider the following subsets *S* (Durante and Jaworski, 2010):

$$\begin{aligned}
S_L &= [0, \alpha] \times [0, 1] \\
S_R &= [1-\alpha, 1] \times [0, 1] \\
S_D &= [0, 1] \times [0, \alpha] \\
S_U &= [0, 1] \times [1-\alpha, 1] \\
S_{LD} &= [0, \alpha] \times [0, \alpha] \\
S_{RU} &= [1-\alpha, 1] \times [1-\alpha, 1] \\
S_V &= [\beta, 1-\beta] \times [0, 1] \\
S_H &= [0, 1] \times [\beta, 1-\beta] \\
S_M &= [\beta, 1-\beta] \times [\beta, 1-\beta].
\end{aligned} \tag{2}$$

Sets S_L, S_R, S_D, S_U, S_{LD} and S_{RU} are called tail sets, and S_V, S_H, S_M are called central sets. Conditional copula functions are defined as conditional on the domain, which in this case is one of the above sets, and are labelled for example C_{S_L}.

Comparing in a certain way the conditional copula function based on one of the tail sets with a function based on one of the central sets, you can examine whether the phenomenon of contagion between the two analysed variables exists, in this case between the chosen indices rates of return.

In this paper, for the purposes of comparing the two copula functions so-called positive quadrant dependence PQD is used (Durante and Jaworski, 2010). We define $C_1 <<_{PQD} C_2$ if for all pairs $(u, v) \in [0, 1]$ $C_1(u, v) \leq C_2(u, v)$, in other words C_2 is greater than C_1 with regard to PQD, if for each pair (u, v) C_2 has higher values than C_1. This means that the dependence between u and v is stronger in the case of the function C_2 than C_1. Using this fact, the construction of sets S and the notion of contagion, you can define such cases:

Market X is contagious to Y, if $C_{S_H} \ll_{PQD} C_{S_L}$.

Market Y is contagious to X, if $C_{S_V} \ll_{PQD} C_{S_D}$.

In case $C_{S_M} \ll_{PQD} C_{S_{LD}}$, we have symmetrical contagion.

Contagion is defined here as an increase in dependence on the lower left tail of the cumulative distribution, compared with the central region of the distribution. This definition does not need to determine directly when we are dealing with a period of crisis, and when with a normal period, but indirectly it is assumed that the crisis occurs when the marginal cumulative distribution function of return rates is lower than the present level α on one or both markets.

There are at least two ways to analyse empirically the relationship between the given conditional copula functions. The first is an attempt to fit a copula function to the data and estimate its parameters. On this basis, you can try to determine the conditional copula functions, and thus determine whether the contagion conditions are met. This approach, however, involves two major problems. Firstly, the fitting of the copula function to the real data usually results in estimation errors which may be multiplied in the process of fitting the conditional copula function. Secondly, determination of the conditional functions can be difficult, especially if you fail to get an explicit formula of this function (Durante and Jaworski, 2010).

Therefore, in this study other non-parametric approach was used following the work of Durante and Jaworski. They proof that it is possible to estimate of the correlation coefficients without using any knowledge about the type of the copula function (Durante and Jaworski, 2010). As we have seen, all the definitions of contagion are based on the comparisons among copulas in the PQD ordering. This ordering is also known to be a concordance ordering in the sense that if $C \ll_{PQD} D$, then $\kappa(C) \leq \kappa(D)$,where κ is any measure of concordance, such as Kendall's τ or Spearman's ρ (Nelsen, 2006; Scarsini, 1984).

Using this fact, one can examine the occurrence of contagion, checking the occurrence of the following relationships:

Market X is contagious to Y, if $\kappa\left(C_{S_V}\right) \leq \kappa\left(C_{S_L}\right)$.
Market Y is contagious to X, if $\kappa\left(C_{S_H}\right) \leq \kappa\left(C_{S_D}\right)$.
In case $\kappa\left(C_{S_M}\right) \leq \kappa\left(C_{S_{LD}}\right)$, we have symmetrical contagion.

A measure based on Spearman's rank correlation coefficient ρ is used in the remaining part of the paper. Because this ratio is calculated for the conditional copula function, it is referred to as the conditional correlation coefficient (Dobric, Frahm, Schmid, 2007).

$$\rho_S = \frac{12}{n_S}\sum_{i\in I_S}\frac{r_S(u_i)}{n_S}\frac{r_S(v_i)}{n_S} - 3, \tag{3}$$

where: ρ_S – conditional Spearman's rank correlation coefficient,
n_S – number of observations in set *S*,
I_S – index of observation belonging to set *S*,
r_S – rank of observation in set *S*.
To assess the statistical significance of the results, a bootstrap method was used (Schmid and Schmidt, 2006; 2007).

There were five steps in calculations of conditional Speraman'sρ:

1. Choose pair of measures/indexes
2. Specify subsets S for α = 0.05 and β = 0.1, for a given lag
3. Compute ρ_S for the subsets *S*
4. Compute confidence intervals of ρ_S (Schmid and Schmidt, 2006; 2007) with confidence level 0.05, 10 000 iterations.

3. Data description

To validate financial contagion hypothesis we used logarithmic weekly returns from 19 chosen world market indexes, and split them into 6 groups. One of the main criterion of choosing these particular markets was availability of data for the longest possible period:

1. Leading European markets: Germany, France, United Kingdom.
2. Smaller European Markets: Greece, Spain, Italy.
3. Emerging European Markets: Poland, Hungary, Czech Republic.
4. North America without USA: Canada, Mexico.
5. South America: Brazil, Argentina.
6. Asia: Japan, China, India, Hong Kong, Singapore.

The synthetic measure was constructed for each of the group based on gradient method (Siedlecki and Siedlecka, 1990.

Table 1 reports summary statistics of stock market indices' weekly returns for all 19 countries. In Table 2 we show statistics of the weekly stock markets' synthetic measures. And Table 3 reports summary statistics of the monthly real economy synthetic measures and log returns of S&P 500 index. The statistics are based on the entire sample period and show significant differences in mean and variance. From results of Augmented Dickey-Fuller test (ADF) (Dickey and Fuller, 1979) we see that all time series are stationary.

Table 1. Descriptive statistics of log returns

	Germany	France	United Kingdom	Greece	Spain
Number of observations	706	706	706	706	706
Mean	0.00037	-0.00057	-0.00012	-0.00307	-0.00055
Variance	0.00106	0.00091	0.00061	0.00189	0.00097
ADF statistic	-7.01493	-6.34957	-7.32325	-5.26571	-7.06785
ADF p-value	3.02E-10	1.65E-08	4.30E-11	5.66E-06	2.17E-10
	Italy	Poland	Czech Republic	Hungary	Canada
Number of observations	706	706	706	706	706
Mean	-0.00129	0.00046	0.00089	0.00118	0.00060
Variance	0.00104	0.00123	0.00098	0.00124	0.00066
ADF statistic	-7.51955	-7.44215	-6.31493	-5.95895	-6.01845
ADF p-value	1.21E-11	2.00E-11	2.02E-08	1.50E-07	1.08E-07
	United States	Mexico	Brazil	Argentina	Japan
Number of observations	706	706	706	706	706
Mean	0.00017	0.00244	0.00177	0.00243	-0.00055
Variance	0.00070	0.00096	0.00126	0.00229	0.00085
ADF statistic	-5.90919	-7.28421	-6.17381	-6.29636	-5.83729
ADF p-value	1.98E-07	5.52E-11	4.52E-08	2.25E-08	2.92E-07
	India	China	Hong Kong	Singapore	
Number of observations	706	706	706	706	
Mean	0.00200	0.00052	0.00031	0.00011	
Variance	0.00137	0.00123	0.00107	0.00082	
ADF statistic	-8.75757	-5.20587	-6.59872	-25.70400	
ADF p-value	2.67E-15	7.59E-06	3.82E-09	4.71E-39	

Source: Own analysis.

Table 2. Descriptive statistics of data

	Big European	Smaller European	East European	North American	South American	Asian
Number of observations	706	706	706	706	706	706
Mean	0.51698	0.51051	0.56817	0.59230	0.57070	0.48613
Variance	0.01082	0.01153	0.00841	0.00719	0.00918	0.00645
ADF statistic	-7.01256	-6.39498	-6.38723	-5.07942	-26.46330	-5.56832
ADF p-value	3.06E-10	1.27E-08	1.33E-08	1.4e-005	4.34E-38	1.22E-06

Source: Own analysis.

In the second round of calculations we used logarithmic monthly returns from the stock market index of United States and three macroeconomic ratios:

1. Index of production
2. Unemployment rate
3. CPI

A synthetic measure was constructed based on macroeconomic ratios.

Table 3. Descriptive statistics of data

	US	S&P 500
Number of observations	298	298
Mean	0.00013	0.00577
Variance	0.00233	0.00220
ADF statistic	-3.71160	-4.66845
ADF p-value	0.003973	9.26E-05

Source: Own analysis.

4. Empirical results

In this section we present results of estimating contagion in financial and real markets. In first part we analyse reaction of stock markets (weekly data) and United States economy (monthly data) to the crisis in US. In second part we confirmed our results using bootstrap because of small number of available data.

4.1. Raw data analysis

Our results are presented in tables 4 and 5 where in column S_L ρ_S values are provided for set S_L, in column S_V ρ_S values are provided for set S_V, columns S_{Ld} and S_{Lu} contain respectively lower and upper boundaries for confidence intervals of ρ_S for set S_L. Columns S_{Vd} and S_{Vu} have analogical meaning. If $S_{Vu}<S_{Ld}$, the dependence between markets in times of distress in the first market is significantly

greater than dependence in normal times, which can be acknowledged as a proof of contagion. These situations are marked in bold.

Table 4. Contagion from US market to stock markets synthetic measures

Lag	S_L	S_V	S_{Ld}	S_{Lu}	S_{Vd}	S_{Vu}
US market to leading European markets						
0	0.5011	0.6541	0.4684	0.5338	0.6522	0.6561
1	**0.1216**	- 0.0270	0.0612	0.1819	- 0.0307	- 0.0234
2	- 0.1874	- 0.0315	- 0.2471	- 0.1277	- 0.0351	- 0.0278
4	- 0.0605	0.0090	- 0.1215	0.0005	0.0054	0.0127
6	**0.1955**	- 0.0725	0.1367	0.2544	- 0.0762	- 0.0689
US market to smaller European markets						
0	0.5807	0.5101	0.5409	0.6204	0.5076	0.5126
1	**0.1734**	0.0057	0.1134	0.2334	0.0018	0.0096
2	- 0.0020	- 0.0304	- 0.0629	0.0590	- 0.0341	- 0.0268
4	- 0.0838	0.0290	- 0.1447	- 0.0228	0.0253	0.0327
6	**0.1283**	- 0.0307	0.0682	0.1884	- 0.0344	- 0.0270
US market to emerging European markets						
0	0.3465	0.3676	0.3020	0.3910	0.3649	0.3703
1	**0.1317**	0.0154	0.0703	0.1930	0.0117	0.0190
2	- 0.0398	0.0587	- 0.0992	0.0196	0.0552	0.0621
4	**0.1246**	- 0.0356	0.0656	0.1837	- 0.0393	- 0.0319
6	**0.1501**	- 0.0580	0.0905	0.2098	- 0.0616	- 0.0543
US market to North American markets (without US)						
0	**0.7510**	0.6373	0.7203	0.7817	0.6355	0.6391
1	- 0.1846	- 0.0827	- 0.2471	- 0.1221	- 0.0864	- 0.0790
2	0.0482	0.0119	- 0.0110	0.1073	0.0082	0.0156
4	0.0090	0.0060	- 0.0516	0.0695	0.0022	0.0097
6	0.0387	- 0.0432	- 0.0183	0.0956	- 0.0469	- 0.0395
Contagion from US market to South American markets						
0	0.5031	0.4994	0.4561	0.5501	0.4967	0.5022
1	0.0952	- 0.0629	0.0356	0.1548	- 0.0664	- 0.0593
2	**0.1126**	0.0462	0.0544	0.1708	0.0427	0.0497
4	- 0.2605	0.0373	- 0.3199	- 0.2011	0.0337	0.0409
6	**0.1776**	- 0.0420	0.1197	0.2355	- 0.0455	- 0.0384
Contagion from US market to Asian markets						
0	**0.5039**	0.4117	0.4583	0.5496	0.4089	0.4146
1	**0.2199**	0.0833	0.1640	0.2758	0.0798	0.0868

2	**0.0849**	- 0.0249	0.0249	0.1448	- 0.0286	- 0.0212
4	**0.1375**	- 0.0317	0.0789	0.1962	- 0.0354	- 0.0281
6	**0.1036**	- 0.0235	0.0454	0.1619	- 0.0271	- 0.0200

Source: Own analysis.

Results in Table 4, that the first reaction of bigger and smaller European countries to the crisis in US stock market was after one and six weeks. The dependence between those markets increased significantly first in one week and second in six weeks after decline in US market. Dependence between emerging European markets and US stock market behave in very similar fashion, with delayed reaction after four weeks. There is no delayed reaction, only strong dependence in time of US market decline between this market and two other North American markets. South American dependence increased significantly after two and six weeks, but for Asian markets this tendency held for 0, 1, 2, 4 and 6 weeks. As we can see can see, with exception to North American markets, reaction of all other markets is delayed six weeks, with other delays possible.

Table 5. Contagion from US stock market to US economy

Lag	S_L	S_V	S_{Ld}	S_{Lu}	S_{Vd}	S_{Vu}
0	-0.1005	0.0208	-0.1730	-0.0289	0.0165	0.0251
1	**0.2**	0.0265	0.1313	0.2686	0.0223	0.0307
2	**0.1694**	0.0334	0.0976	0.2412	0.0290	0.0378
3	**0.3403**	-0.0068	0.2658	0.4149	-0.0112	-0.0024
6	0.0561	0.0115	-0.0135	0.1258	0.0074	0.0157

Source: Own analysis.

We see (Table 5) that dependence to American stock market increased in one, two and three month in case on US economy after crisis in American stock market. Our evidence shows, there we can only detect contagion in lagged data, in exact time of decline in stock market returns dependence does not significantly increases.

4.2. Bootstrap analysis

To validate our findings we used a bootstrap formula. We have calculated conditional Spearman's coefficient for bootstrapped data, using 10 000 repetitions.

Table 6. Results of bootstrapped simulations

US market to leading European markets				
Lag	Mean S_L	Mean S_V	Std. dev S_L	Std. dev S_V
0	0.4914	0.6563	0.1566	0.0301
1	0.0969	- 0.0303	0.2138	0.0453
2	- 0.1732	- 0.0281	0.1934	0.0459
4	- 0.0582	0.0188	0.1782	0.0458

6	0.1276	- 0.0552	0.2219	0.0463
US market to smaller European markets				
Lag	Mean S_L	Mean S_V	Std. dev S_L	Std. dev S_V
0	0.5311	0.5093	0.1429	0.0357
1	0.1241	0.0012	0.2092	0.0463
2	0.0297	- 0.0273	0.1929	0.0441
4	- 0.0940	0.0352	0.1682	0.0461
6	0.0644	- 0.0197	0.1992	0.0450
US market to emerging European markets				
Lag	Mean S_L	Mean S_V	Std. dev S_L	Std. dev S_V
0	0.3738	0.3657	0.1604	0.0397
1	0.1382	0.0169	0.2075	0.0452
2	- 0.0616	0.0574	0.2035	0.0438
4	0.1419	- 0.0292	0.1844	0.0450
6	0.1558	- 0.0458	0.1970	0.0451
US market to North American markets without US				
Lag	Mean S_L	Mean S_V	Std. dev S_L	Std. dev S_V
0	0.6666	0.6320	0.1240	0.0309
1	- 0.1311	- 0.0864	0.1972	0.0446
2	0.0884	0.0186	0.2035	0.0446
4	- 0.0031	0.0149	0.1918	0.0451
6	0.0311	- 0.0364	0.1987	0.0453
US market to South American markets				
Lag	Mean S_L	Mean S_V	Std. dev S_L	Std. dev S_V
0	0.4213	0.4890	0.1647	0.0353
1	0.1409	- 0.0663	0.1996	0.0423
2	0.1592	0.0490	0.1849	0.0432
4	- 0.2749	0.0399	0.1723	0.0436
6	0.1493	- 0.0351	0.1991	0.0440
US market to Asian markets				
Lag	Mean S_L	Mean S_V	Std. dev S_L	Std. dev S_V
0	0.4809	0.4077	0.1392	0.0384
1	0.1871	0.0740	0.1794	0.0440
2	0.0338	- 0.0206	0.2002	0.0445
4	0.1114	- 0.0310	0.1988	0.0443
6	0.1377	- 0.0182	0.1977	0.0436

Source: Own analysis.

Table 7. Results of bootstrapped simulations (American stock market to US economy)

Lag	Mean S_L	Mean S_V	Std. dev S_L	Std. dev S_V
0	-0.064985	0.0216929	0.2244063	0.0460779
1	0.1964756	0.0272841	0.2087439	0.0492546
2	0.2244691	0.0242302	0.230296	0.0457555
3	0.3065171	-0.010513	0.2234573	0.0498713
6	0.1273514	0.0141612	0.2263086	0.048947

Source: Own analysis.

As we can see in tables 6 and 7, bootstrapped coefficient are very similar to real values, which indicates that our results are not biased because of small number of observations.

5. Conclusions

We successfully manage to apply the methodology of Durante and Jaworski (2010) and our modification of taxonomic index (Siedlecki, Siedlecka, 1990) to analyse the relationship between the capital market and economy. The relationship between the economy and the financial markets is an obvious one, but our results are important. We find that in US reaction of the real economy to the decline of stock market in US is delayed by about one-three months. It could mean that the stock markets are contagious to the real economy.

The combination of a taxonomic index and a conditional concordance measures seems to be a good tool used for estimating contagion in financial markets and the economy. The methodology presented in our research shows that US stock market is ahead of the other markets. We suppose that medium- and long-term research and the use of macroeconomic data in contrast to the current short-term can lead to very interesting results.

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