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Dynamics of Multivariate Return Series of U.S. Automotive Stock Companies in Conditions of Crisis[†]

A b s t r a c t. This article contains an analysis of dynamic interrelations between log-returns series of three automotive companies listed on the New York Stock Exchange: GM, F and DAI. We consider two periods: before and during crisis. We apply DiagBEKK model and we calculate dynamic conditional correlations. As a result of our research we found that in conditions of crisis there were strong connections between considered stock companies.

K e y w o r d s: DiagBEKK model, dynamic conditional correlation.

1. Introduction

General Motors, Ford and Chrysler, known as the Detroit's Big Three, are the major companies of American automotive industry. They have in common not only strong worldwide position but also problems, among others, with high labor costs as a result of activities of United Auto Workers. This inevitably results in high prices of cars offered, which can be afforded by fewer and fewer potential customers. General Motors, Ford and Chrysler face such problems for several years.

Very high oil prices, soaring in the period from January 2007 to mid-2008, also resulted in fewer Big Three car sales, because of high fuel costs.

Credit crunch, due to the prevailing economic crisis, caused deeper and deeper problems of the Big Three. Dismal financial performance of these companies inevitably resulted in a weakening listing on the New York Stock Exchange[1].

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[1] Chrysler is not listed on NYSE. From 1998 to mid-May 2007, Chrysler were part of DaimlerChrysler AG, later the shares were held by an investment fund Cerberus. At the end of April 2009, declared bankruptcy, Fiat hold 20% of his shares.

This paper contains an analysis of daily log-returns series of three automotive companies listed on the New York Stock Exchange: GM (General Motors), F (Ford Motor Company) and DAI (Daimler AG, for mid-May 2007 as DaimlerChrysler). The goal of this paper is to investigate and describe dependencies between them. The research is made for two periods separately: before and during crisis. This allows us to observe the changes that have taken place.

2. Methodology

Let $\mathbf{r}_t = (r_{1,t}, r_{2,t}, ..., r_{n,t})'$ denote a multivariate time series of returns with the following decomposition

$$\mathbf{r}_t = \boldsymbol{\mu}_t + \mathbf{y}_t, \tag{1}$$

where:

$\boldsymbol{\mu}_t = E(\mathbf{r}_t \mid \Phi_{t-1})$ is conditional mean,

Φ_{t-1} is the information set available at time $t-1$.

Conditional expected value $\boldsymbol{\mu}_t = E(\mathbf{r}_t \mid \Phi_{t-1})$ can be modeled by VARMA models (Tsay, 2002):

$$\boldsymbol{\Phi}(B)\boldsymbol{\mu}_t = \boldsymbol{\varphi}_0 + \boldsymbol{\Theta}(B)\mathbf{a}_t, \tag{2}$$

where:

$\boldsymbol{\varphi}_0$ is n-dimensional vector,

$\boldsymbol{\Phi}(B) = \mathbf{I} - \boldsymbol{\Phi}_1 B - ... - \boldsymbol{\Phi}_p B^p$ and $\boldsymbol{\Theta}(B) = \mathbf{I} - \boldsymbol{\Theta}_1 - ... - \boldsymbol{\Theta}_q B^q$ are two $n \times n$ matrix polynomials,

B^q is back-shift operator: $B^q \mathbf{a}_{i,t} = \mathbf{a}_{i,t-q}$,

$\{\mathbf{a}_t\}$ is a sequence of serially uncorrelated random vectors with mean zero and covariance matrix $\boldsymbol{\Sigma}$.

A general multivariate GARCH model for $\mathbf{y}_t$ is given by equation

$$\mathbf{y}_t = \mathbf{H}_t^{1/2} \boldsymbol{\varepsilon}_t, \tag{3}$$

where:

$\boldsymbol{\varepsilon}_t$ is n-dimensional i.i.d. process with zero mean and identity covariance matrix,

$\mathbf{H}_t^{1/2}$ is a $n \times n$ matrix satisfying $\mathbf{H}_t^{1/2}\left(\mathbf{H}_t^{1/2}\right)' = \mathbf{H}_t$,

$E(\mathbf{y}_t \mid \Phi_{t-1}) = \mathbf{0}$ and $E(\mathbf{y}_t \mathbf{y}_t' \mid \Phi_{t-1}) = \mathbf{H}_t$.

Specific MGARCH (multivariate GARCH) model is described by parameterization of positive definite covariance matrix $\mathbf{H}_t$.

The BEKK model have been proposed by Engle and Kroner (1995). The following equation defines BEKK(p,q,K) model:

$$\mathbf{H}_t = \mathbf{C}_0'\mathbf{C}_0 + \sum_{k=1}^{K}\sum_{i=1}^{q}\mathbf{A}_{ik}'\mathbf{y}_{t-i}\mathbf{y}_{t-i}'\mathbf{A}_{ik} + \sum_{k=1}^{K}\sum_{i=1}^{p}\mathbf{G}_{ik}'\mathbf{H}_{t-i}\mathbf{G}_{ik}, \tag{4}$$

where:

$\mathbf{C}_0, \mathbf{A}_{ik}$ and $\mathbf{G}_{ik}$ are matrices of dimension $n \times n$ but $\mathbf{C}_0$ is upper triangular matrix,

K term determines generality of the model.

On this model positivity of matrix $\mathbf{H}_t$ can be easily imposed. To reduce number of parameters one can impose a diagonal BEKK model (DiagBEKK) where matrices $\mathbf{A}_{ik}$ and $\mathbf{G}_{ik}$ are diagonal. Consequently, the generality of the model decreases. We can write equation for the simplest DiagBEKK model with $K = 1$ for GARCH(1,1) model in following way:

$$\mathbf{H}_t = \mathbf{C}_0'\mathbf{C}_0 + \mathbf{A}_{11}'\mathbf{y}_{t-1}\mathbf{y}_{t-1}'\mathbf{A}_{11} + \mathbf{G}_{11}'\mathbf{H}_{t-1}\mathbf{G}_{11}. \tag{5}$$

3. Empirical Analysis

This paper contains an analysis of daily log-returns series of three automotive companies listed on the New York Stock Exchange: General Motors (NYSE:GM), Ford Motor Company (NYSE:F) and Daimler AG (NYSE: DAI). There are some indications that the crisis in the automobile industry connected with the current economic crisis began in mid-2008. In our analysis, a start date for crisis in the automotive industry is set on 1 July 2008. An investigation is made for two periods separately: before crisis (January 3, 2007 to June 30, 2008) and during crisis (July 1, 2008 to May 5, 2009). We use following designations for time-series: GM_1, F_1, DAI_1 and GM_2, F_2, DAI_2 respectively.

Figure 1 presents the plots of daily log-returns series for investigated companies. One can see that in mid-2008 dynamics of examined series has changed. There is a significant increase in volatility. This is most strongly marked in the period from mid-September to the end of December. This was the period of greatest uncertainty in financial markets: September 15 – the collapse of Lehman Brothers, which caused a crash on the American Stock Exchange, early October – events in Iceland. In addition, due to rapid increase in oil prices (by mid-2008) and credit crunch, car manufacturers have noted the next drop in sales. General Motors, along with Chrysler, has started efforts to receive aid from the American governments because of the threat of bankruptcy. These events coincide in time with periods of increased volatility in the ex-

amined series. December 19, 2008, U.S. president has approved financial help for General Motors and Chrysler. From that moment, we can observe some sedation, which lasts only until mid-February 2009. This corresponds to the moment when General Motors and Chrysler have asked the government for more financial support (February 18).

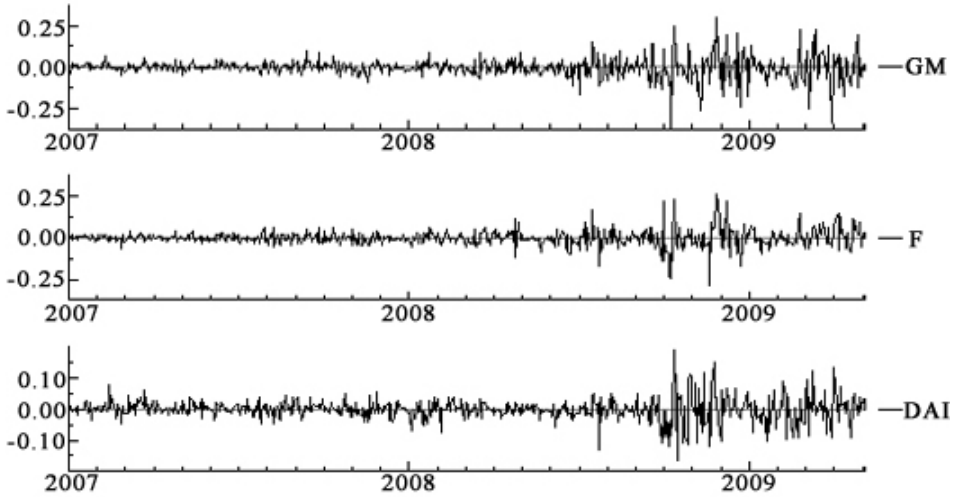

Figure 1. GM, F and DAI – daily log-returns. Period 3.01.2007 – 5.05.2009

We calculate the most important descriptive statistics of the return series for first and second period separately. The results are contained in Table 1.

Table 1. Descriptive statistics of the return series

	Min	Mean	Max	Std. deviation	Skewness	Kurtosis
GM_1	-0.114	-0.003	0.096	0.029	0.096	1.164
GM_2	-0.373	-0.009	0.301	0.097	-0.281	1.749
F_1	-0.113	-0.001	0.111	0.026	0.012	2.167
F_2	-0.288	-0.001	0.259	0.072	0.088	3.120
DAI_1	-0.076	0.000	0.079	0.020	-0.032	1.417
DAI_2	-0.165	-0.002	0.199	0.053	0.050	1.219

Clear differences between log-returns series of the investigated companies have been noted based on chart already. These observations are confirmed by calculated descriptive statistics. In all cases during the crisis, there is stronger volatility and extreme values – both positive and negative – are higher. The changes of skewness vary for each series. We observe that log-return series of GM had positive skew in the first period and during the crisis it changed to negative. Negative returns of General Motors occurred more often because of the many problems of this company and necessity of government help. Return series of Daimler AG behaved conversely. Ford was characterized by positive skewness and during the crisis asymmetry was stronger. More frequent positive

returns for Ford probably resulted from a better perception of the manufacturer by investors – company did not ask for government aid despite the prevailing situation. In all cases series were leptokurtic.

Table 2. Parameter estimates for the fitted DiagBEKK model for two periods: before (first period) and during crisis (second period). DF is the degree of freedom for Student's *t* error distribution

	First period		Second period	
	Estimate	*p*-value	Estimate	*p*-value
$\boldsymbol{\varphi}_{01}$	-0.0019	0.1685	-	-
$\boldsymbol{\varphi}_{02}$	-0.0005	0.6900	-	-
$\boldsymbol{\varphi}_{03}$	0.0004	0.6621	-	-
$\mathbf{C}_{0,11}$	0.0143	0.0000	0.0428	0.0126
$\mathbf{C}_{0,12}$	0.0207	0.0000	0.0171	0.0007
$\mathbf{C}_{0,13}$	0.0033	0.0000	0.0169	0.0000
$\mathbf{C}_{0,22}$	0.0040	0.2478	0.0183	0.0130
$\mathbf{C}_{0,23}$	0.0043	0.0118	0.0041	0.4872
$\mathbf{C}_{0,33}$	0.0000	0.7009	0.0000	0.1715
$\mathbf{G}_{11,11}$	0.8511	0.0000	0.8154	0.0000
$\mathbf{G}_{11,22}$	0.5137	0.0000	0.9081	0.0000
$\mathbf{G}_{11,33}$	0.9541	0.0000	0.9200	0.0000
$\mathbf{A}_{11,11}$	0.1685	0.0626	0.3839	0.0260
$\mathbf{A}_{11,22}$	-0.2554	0.0054	0.2056	0.0703
$\mathbf{A}_{11,33}$	-0.1260	0.0209	-0.2426	0.0000
DF	-	-	5.3920	0.0000

We applied DiagBEKK model to characterize the dynamics of multivariate time series and changing dependencies between examined companies before and during the crisis. The results are presented in Table 2. We fit DiagBEKK model with Normal distribution in the first period and Student's *t* in the second.

Figure 2 presents the plots of dynamic conditional correlations from model fitted for the first period. In all cases there were only positive conditional correlations between examined series.

The strongest dependency was between General Motors and Ford. The mean of conditional correlations between them equals 0.67, the lowest value equals 0.12, the highest: 0.78. The mean of conditional correlations between GM and DAI equals 0.67, the lowest value equals 0.12, the highest: 0.78. Conditional correlations between stock returns of Ford and Daimler were at the

lowest level with mean 0.35, minimum 0.11, maximum 0.48 and characterized by strongest dynamics.

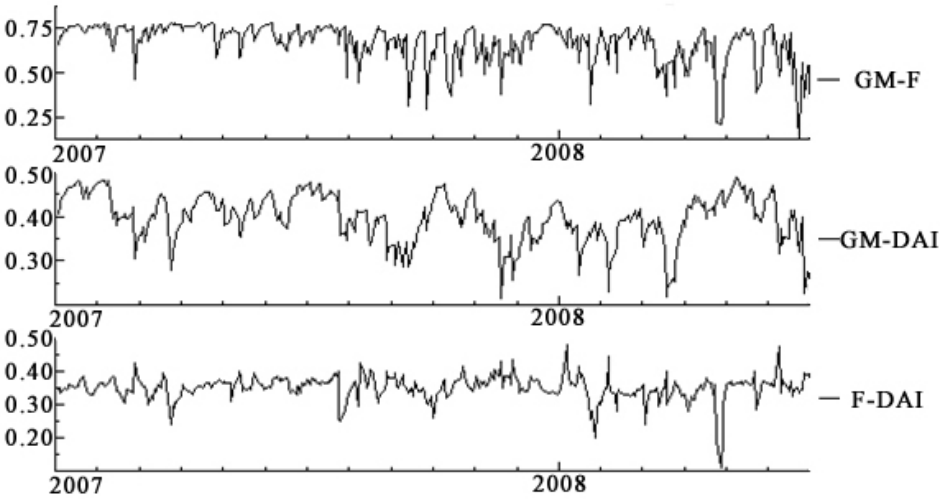

Figure 2. Dynamic conditional correlations. Period 3.01.2007 – 30.06.2008

It can be concluded that companies belonging to the U.S. producers of the Detroit Three (GM, F) are much more strongly linked to each other. In the period before the crisis, linkages with companies of the Big Three (GM, F) were not high despite the fact that Daimler was connected to May 2007 with Chrysler.

Figure 3 presents the plots of dynamic conditional correlations during the crisis. Once again, the strongest dependency was between General Motors and Ford Motor Company. The mean of conditional correlations between them equals 0.62 (small decrease, compared with the last period), the lowest value equals 0.43, the highest: 0.8. Strength of connections between GM, F and DAI increased in condition of crisis. The mean of conditional correlations between General Motors and Daimler equals 0.44, the lowest value equals -0.33, the highest: 0.82. Conditional correlations between Ford and Daimler were as follows: mean 0.47 (increase), minimum -0.24, maximum 0.76.

The most interesting behavior occur in October, 2008. Strength of dependencies between General Motors and Ford increased until October 14, to the value 0.8. Then conditional correlations decreased rapidly to the value 0.44 (October, 31). Quite the contrary in those days was behaviour of conditional correlations of General Motors – Daimler and Ford – Daimler. Interestingly, they changed the sign from positive to negative, which remained so far one week starting October, 10 and it reached a value close to -0.3. Perhaps it was a reaction to earlier events in Iceland, which shook the financial markets. A similar phenomenon, but with less power changes also occurred in late November and December. On November 28, 2008 conditional correlations of Gen-

eral Motors - Ford increased to a value of 0.77, while the conditional correlations of General Motors - Daimler and Ford - Daimler fell almost to zero. This was perhaps the result of the events associated with the efforts of General Motors for government aid because of the threat of bankruptcy. Since the beginning of 2009 dynamics of the analyzed dependencies reduced.

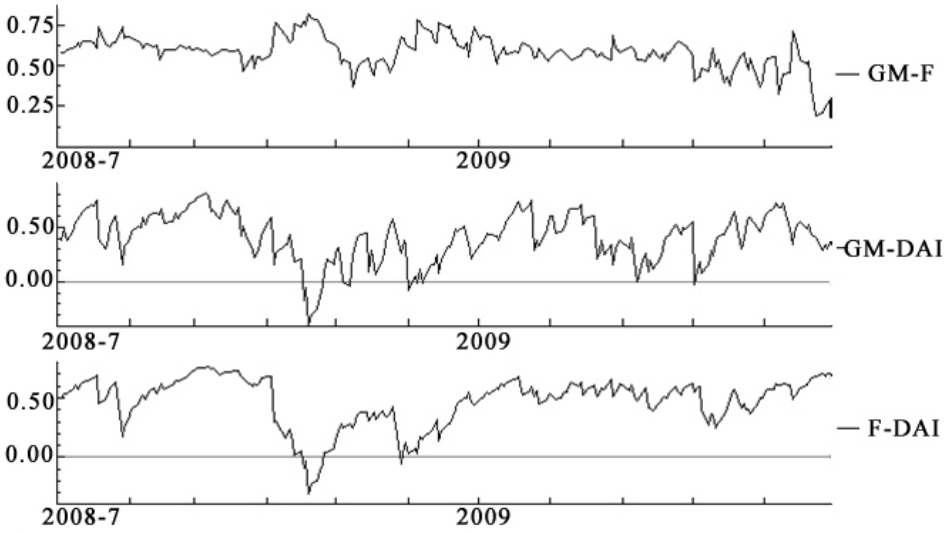

Figure 3. Dynamic conditional correlations. Period 1.07.2008 – 5.05.2009

We conclude that the strongest linkages were between General Motors and Ford Motor Company. It turned out that the estimated strength of linkages between them was high all the time, but decreased slightly during the crisis. This is an interesting phenomenon, because one would expect a completely different perception by investors of the two companies during the crisis, because of the much larger GM's financial problems that led to the threat of bankruptcy. The strength and dynamics of linkages between companies in the U.S. automotive market and Daimler rose during the crisis. Numerous problems faced by car manufacturers, have contributed to increase the relationship between GM, F and DAI. In time of crisis this may be an indication for investors, who should take into account the presence of strong dependencies between the companies belonging to the same industry.

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Dynamika wielowymiarowych szeregów czasowych notowań spółek amerykańskiego rynku motoryzacyjnego w warunkach kryzysu

Z a r y s t r e ś c i. W artykule przeprowadzono analizę dynamiki powiązań pomiędzy szeregami zwrotów logarytmicznych trzech spółek rynku motoryzacyjnego notowanych na nowojorskiej giełdzie: GM, F i DAI. Badanie przeprowadzone zostało dla dwóch okresów: przed i w czasie kryzysu. Dopasowano model DiagBEKK, uzyskując oszacowania dynamicznych korelacji warunkowych. Wyniki badania wskazują na występowanie w czasie kryzysu silnych powiązań pomiędzy badanymi spółkami.

S ł o w a k l u c z o w e: model DiagBEKK, dynamiczna korelacja warunkowa.