USE OF MULIFACTOR MODELS WITH GARCH STRUCTURE IN CARBON EMISSIONS RISK MANAGEMENT

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Abstract: Tightening the environmental norms that result from the priorities of the EU 2030 Energy and Climate Package and the reform of the EU ETS have caused the necessity to implement an effective system of managing the risk of carbon dioxide emission and integrate it with the existing enterprise management system. Evaluation of the direction and strength of correlation between EUA price changes and energy companies stock price returns is crucial from point of view the managerial staff making proper decisions about the use of the CO_2 emission permits by energy companies. It is an important stage of carbon emission risk management process. The aim of this paper is to verify the possibility of use the multifactor models with GARCH structure as a tool supporting the carbon emission management process in energy companies. Empirical analysis is connected with the estimation of multifactor models with GARCH structure in the Phase II and Phase III of the EU ETS functioning for two groups of Polish energy companies: group of the Respect Index companies and others. Such an approach allows to check whether the Respect Index companies are more robust than others on the carbon emission risk, in particular the EUA price risk associated with the intensification works on modifying the EU ETS functioning. We found that the impact of EUA price changes on energy companies stock returns and their volatility is statistically insignificant in case of all Respect Index companies.

Keywords: CO_2 emissions, risk management, European Union Allowances, multifactor model, GARCH

1. INTRODUCTION

An important tool of the EU's climate and energy policy for achieving greenhouse gas emissions reduction goal from the large–scale facilities in the power sector is the European Union Emission Trading System (EU ETS). European Emission Allowances (EUA), which are allocated among the power and industrial installations covered by this trading system, permit to emit determined quantity tonnes of carbon dioxide. Due to the negotiable nature of these allowances, strategic decisions about reducing own emission and selling the surplus of allowances or conversely, buying additional allowances in order to cover an increased GHG emission will be already made at the enterprise level. This solution was supposed to reduce greenhouse gases emission into the atmosphere in a cost-effective way, according to the "pollutant pays" principle (Graczyk and Graczyk, 2011). Therefore, the EU takes actions that aim at strengthening the EU ETS as an instrument that stimulates investments into the low-emission energy through solving the problem of surpluses of allowances for sale (Brink et al., 2016). Tightening the environmental norms that result from the priorities of the EU 2030 Energy and Climate Framework (Ringel and Knodt, 2018) and the proposed by the European Commission reform of the EU ETS (Post-2020 reform of the EU Emissions Trading System, 2017) have created the necessity to implement an effective system of managing the risk of carbon dioxide emission and integrate it with the existing enterprise management system. According to Wahyuni and Ratnatunga (2015) an effective carbon management system enables a company to identify its carbon emissions sources, measure its emissions inventory, and then explore alternative options to cut its emissions level. Carbon emission risk management system, that is fitted to the individual company's needs and focused on ecological innovations issues, allows the company not only to comply with new carbon-constraint regulations, but also to profit from its energy efficiency increase. As Orsato (2009) stressed energy utilities operating in deregulated markets ought to be more open to explore new tools supporting carbon emission risk management, in particular the carbon emissions allowances price risk management than energy utilities operating in regulated markets. It is due to the fact that the first group of energy utilities have developed appropriate skills and gained necessary experience in running the business activity under conditions of uncertainty when they had to trade power and adjust their power sources based on changing costs of energy fuels. Moreover, the system of CO_2 emission allowances managing, connected with current control that the upper level of allowed emission is not exceeded and sales of surpluses of CO_2 emission allowances at attractive for enterprises price lead to strengthening the competitive advantage of enterprises (Veith et al., 2009). On the other hand, the volatility of the CO_2 emission allowance prices generates additional risk factor for energy sector companies (Fan et al., 2017).

Taking above into consideration, the aim of this paper is to verify the possibility of use the multifactor models with GARCH structure as a tool supporting the carbon emission management process in energy companies. Empirical analysis is connected with the estimation of multifactor models with GARCH structure in the Phase II and Phase III of the EU ETS functioning for two groups of Polish energy companies: group of the Respect Index companies and others. Such an approach allows to check whether the Respect Index companies are more robust than others on the carbon emission risk, in particular the EUA price risk associated with the intensification works on modifying the EU ETS functioning.

2. METHODOLOGY OF RESEARCH

Identification and understanding the nature of relationship between carbon allowances prices variability and stock prices changes are especially important for industries which have to comply with the EU ETS. Oberndorfer (2009) investigated the impact of EUA prices changes on European electricity firms' stock returns by means of multifactor market model. Exogenous variables commonly used in this type of analysis refer to production factors, such as fuel prices or electricity prices (Mo et al., 2012; Freitas and Silva, 2015). In order to gain a deeper understanding of carbon prices influence on stock returns of energy sector companies the basic multifactor market model is extended by using a broad spectrum of GARCH model specifications with different distributions for model innovations (Laurent, 2013). We calibrated the asymmetric power GARCH(p,q) (APARCH(p,q)) model by introduction three exogenous variables into the equation (3), describing the impact of carbon allowances, coal and electricity prices volatility on stock prices volatility:

$$r_t = \varphi_0 + \varphi_1 r_{m,t} + \varphi_2 r_{EUA,t} + \varphi_3 r_{c,t} + \varphi_4 r_{el,t} + \varphi_5 r_{t-1} + \varphi_6 D_t + \varepsilon_t \qquad (1)$$

$$\varepsilon_t = \vartheta_t \sigma_t, \qquad \vartheta_t \sim i.i.d.\, D(0,1) \qquad (2)$$

$$\sigma_t^{\delta} = \omega + \omega_1 v_{EUA,t} + \omega_2 v_{c,t} + \omega_3 v_{el,t} + \sum_{i=1}^{q} \alpha_i (|\varepsilon_{t-i}| - \gamma_i \varepsilon_{t-i})^{\delta} + \sum_{j=1}^{p} \beta_j \sigma_{t-j}^{\delta} \qquad (3)$$

where:

r_t – log return of energy company stock on day t,

$r_{m,t}$ – market index return,

$r_{EUA,t}$ – percentage change in the EUA prices,

$r_{c,t}$ – percentage change in coal prices,

$r_{el,t}$ – percentage change in electricity prices,

D_t – dummy variable describing extreme changes in returns series,
ε_t – error term with the conditional standard deviation σ_t,
ϑ_t is an independently and identically distributed process with zero mean and unit variance,
D(.) is a probability density function
$\omega > 0$, $\alpha_i \geq 0$ (i = 1, 2, …, q), $\beta_j \geq 0$ (j = 1, 2, …, p), δ ($\delta > 0$) is connected with a Box-Cox transformation of σ_t, γ_i reflects the leverage effect ($-1 < \gamma_i < 1$ for i =1,2,…,q).
Phi coefficients in model (1) are the systematic risk measures that illustrate sensitivity of the energy firm stock prices on given price factor. In the case when $\varphi_i < 0$ (i=1,2,3,4), the increase of i-th risk factor causes ceteris paribus the decrease of energy firm stock prices. In turn, $\varphi_i > 1$ means that the increase of i-th risk factor causes ceteris paribus the increase of energy firm stock prices, but the stock prices changes are bigger compared to i-th risk factor changes. When $0 < \varphi_i < 1$, the increase of i-th risk factor causes ceteris paribus the increase of energy firm stock prices but at slower rate. It is worth stressing that conditional standard deviation of the idiosyncratic error term of energy firm stock prices is also determined by external factors due to the inclusion of the EUA price volatility (ν_{EUA}), as well as coal price volatility (ν_c), and electricity price volatility (ν_{el}), in the equation (3).
Parameters of multifactor models with GARCH structure are estimated by means of the quasi maximum likelihood method. The best model in each class is chosen on the basis of: the parameters significance; Schwarz information criterion (SIC); the residuals tests: the Box-Pierce test for autocorrelation effect, the Engle's test for ARCH effect; the Nyblom test for checking the constancy of parameters over time; the Engle and Ng set of tests for existing leverage effect (Laurent, 2013).

3. EMPIRICAL RESULTS AND DISCUSSION

Empirical research are conducted for the chosen companies from energy sector quoted on the main market of the Warsaw Stock Exchange (WSE) that are covered by the EU ETS. Data on daily stock and WIG20 prices are obtained from the InfoStrefa Service and cover the period from January 4, 2010 to December 29, 2017. The choice of the research period is connected with the privatization process of Polish energy sector and following it debut of Polish stock exchange companies. The ICE EUA Futures continuous contracts series retrieved from the Quandl Database are taken as benchmark EUA prices for carbon emission risk management purposes. We convert these prices from Euros to Polish zloty using the closing spot EUR-PLN exchange rate obtained from Forex market. Series of coal prices is constructed on the basis of Rotterdam Coal Futures Continuous Contract prices obtained from Quandl Database through their conversion into Polish zlotys according to the Forex closing spot USD-PLN exchange rate. As a proxy of market electricity prices we use the IRDN index of the Day-Ahead Market of the Polish Power Exchange, that refers to weighted average price of all transactions on the trading session, calculated for particular delivery date.
The sample period is divided into two subsamples: 2010-2012 and 2013-2017, corresponding to the Phase II and Phase III of the EU ETS functioning. In each subsample, the multifactor model with GARCH structure (1) – (3) is estimated in order to evaluate the impact of CO_2 emission allowance prices on the Polish energy companies stocks prices in two cases: the group of the Respect Index companies (PGE SA and ZEW Kogeneracja SA have been continuously listed in the Respect Index since 2011, Tauron PE SA and Energa SA - since respectively 2013 and 2014) and others (Enea SA, Polenergia SA, ZE PAK SA) (see Table 1-2).

Table 1
Estimation results of the multifactor model with APARCH(1,1) structure –Phase II

Parameter/Statistic	Enea	Kogeneracja	PGE	Polenergia	Tauron
Constant (mean)	-0.052 [0.198]	0.042 [0.309]	-0.054 [0.162]	-0.112 [0.009]	-0.049 [0.315]
WIG20	0.374 [0.000]	0.241 [0.000]	0.669 [0.000]	0.367 [0.000]	0.563 [0.000]
EUA	0.006 [0.736]	-0.025 [0.171]	-0.016 [0.308]	0.0008 [0.960]	0.027 [0.063]
Dummy	0.884 [0.000]	-0.143 [0.001]	-	-	-
Constant (variance)	0.061 [0.104]	0.459 [0.089]	0.125 [0.127]	0.784 [0.077]	0.112 [0.424]
EUA_volatility	0.0135 [0.059]	0.00013 [0.991]	0.0015 [0.379]	0.0012 [0.918]	0.013 [0.177]
IRDN_volatility	-	-	0.0012 [0.098]	-	0.0019 [0.074]
ARCH(Alpha1)	0.216 [0.004]	0.270 [0.001]	0.124 [0.051]	0.272 [0.088]	0.271 [0.069]
GARCH(Beta1)	0.616 [0.000]	0.345 [0.084]	0.813 [0.000]	0.643 [0.000]	0.683 [0.001]
APARCH(Gamma1)	-	-	0.345 [0.049]	-	-
APARCH(Delta)	2	2	1.406 [0.000]	2	2
Student DF	4.873 [0.000]	3.545 [0.000]	8.580 [0.009]	2.892 [0.000]	6.142 [0.000]
BIC	3.542	3.776	3.224	3.637	3.625
Box-Pierce(5) test	6.995 [0.221]	3.366 [0.499]	5.645 [0.342]	4.359 [0.499]	3.224 [0.665]
ARCH(5) test	0.917 [0.470]	0.701 [0.623]	0.109 [0.990]	0.591 [0.707]	1.001 [0.416]
Joint Nyblom test	1.907	1.679	1.909	2.027	1.426
Individual Nyblom	SP	SP	SP	SP	SP
Sign Bias test	0.250 [0.803]	0.965 [0.334]	1.024 [0.306]	0.521 [0.602]	0.177 [0.859]
Negative Size Bias test	0.552 [0.581]	0.120 [0.904]	0.944 [0.345]	0.939 [0.348]	0.419 [0.675]
Positive Size Bias test	0.320 [0.749]	1.063 [0.288]	0.402 [0.688]	0.035 [0.972]	0.841 [0.400]

Source: Own calculations in G@RCH 7. Note: all variables, that had statistically insignificant impact on the stock returns of energy compannie, were eliminated; SP – all parameters are not time-varying; p-value in brackets.

Table 2
Estimation results of the multifactor model with APARCH(1,1) structure –Phase III

Parameter	Enea	Energa	Kogeneracja	PGE	Polenergia	Tauron	ZE PAK
Constant (mean)	-0.058 [0.152]	0.036 [0.399]	0.013 [0.548]	-0.014 [0.687]	-0.054 [0.157]	-0.031 [0.471]	-0.109 [0.011]
WIG20	0.562 [0.000]	0.066 [0.198]]	-0.009 [0.559]	0.907 [0.000]	0.099 [0.037]	0.842 [0.000]	0.397 [0.000]
EUA	-0.030 [0.024]	-0.014 [0.154]	-0.010 [0.237]	-0.012 [0.355]	-0.016 [0.088]	-0.004 [0.801]	0.0007 [0.959]
Coal	-0.039 [0.096]	-	-	-0.078 [0.029]	-	-	-
IRDN	-	-	-	-0.014 [0.015]	-	-0.009 [0.094]	-
Dummy	1.031 [0.000]	8.370 [0.000]	-	-	0.995 [0.000]	0.599 [0.000]	0.986 [0.000]
Constant (variance)	0.053 [0.125]	0.019 [0.256]	0.009 [0.412]	0.067 [0.098]	0.198 [0.027]	0.034 [0.193]	0.047 [0.152]
EUA_volatility	0.0116 [0.053]	0.0004 [0.673]	0.0001 [0.841]	0.0003 [0.714]	0.0021 [0.153]	0.0001 [0.858]	0.0029 [0.000]

IRDN_volatility	0.0017 [0.019]	0.0006 [0.194]	-	0.0065 [0.003]	-	0.0013 [0.024]	-
ARCH(Alpha1)	0.067 [0.015]	0.006 [0.103]	0.113 [0.003]	0.018 [0.063]	0.015 [0.055]	0.033 [0.036]	0.069 [0.013]
GARCH(Beta1)	0.917 [0.000]	0.986 [0.000]	0.760 [0.000]	0.956 [0.000]	0.952 [0.000]	0.929 [0.000]	0.895 [0.000]
APARCH (Gamma1)	0.627 [0.081]	-	0.178 [0.001]	-	-	-	-
APARCH(Delta)	1.108 [0.019]	2	2	2	2	2	2
Student DF	6.329 [0.000]	4.913 [0.000]	3.098 [0.000]	7.050 [0.000]	3.244 [0.000]	8.794 [0.000]	4.401 [0.000]
BIC	4.031	4.002	3.617	3.818	4.215	3.839	4.018
Box-Pierce(5) test	7.810 [0.167]	8.199 [0.146]	1.416 [0.923]	8.710 [0.121]	5.646 [0.342]	5.655 [0.341]	5.031 [0.412]
ARCH(5) test	0.726 [0.604]	0.123 [0.987]	0.444 [0.818]	1.111 [0.353]	1.139 [0.338]	1.332 [0.248]	0.848 [0.516]
Joint Nyblom test	3.221	2.404	1.346	1.621	2.305	2.389	2.159
Individual Nyblom test	WIG20 1.403***	SP	SP	SP	WIG20 0.807***	SP	WIG20 1.081***
Sign Bias test	0.561 [0.575]	0.146 [0.884]	1.143 [0.253]	0.996 [0.319]	0.908 [0.364]	1.226 [0.220]	0.336 [0.737]
Negative Size Bias test	0.514 [0.608]	0.417 [0.677]	1.367 [0.172]	0.267 [0.790]	0.656 [0.512]	1.472 [0.141]	0.639 [0.523]
Positive Size Bias test	0.738 [0.460]	0.394 [0.694]	0.771 [0.441]	1.114 [0.274]	0.631 [0.528]	0.580 [0.562]	0.987 [0.324]

Source: Own calculations in G@RCH 7.

In case of each energy company one can notice that coefficients describing the influence of market risk are statistically significant in the first subsample, wherein the impact of the WSE's conjuncture on the value of Kogeneracja and Polenergia stocks is statistically insignificant in the second subsample. In the Phase II, all energy companies are defensive in relation to the WIG20 portfolio, which means that in the period when the value of the market portfolio grows by 1% ceteris paribus, then the value of energy companies stocks will grow on average from 0.241% (Kogeneracja) to 0.669% (PGE). In the Phase III, the increase of the WIG20 index by 1% may contribute to the increase in the energy companies portfolio value at least by 0.099% (Polenergia), and at most by 0.907% (PGE). In turn, the estimation results provide empirical evidence for insignificant impact of the EUA price changes on stock returns of the most of Polish energy companies. The exception is Tauron, for which it is observed a positive and significant impact of the EUA price changes on its stock price returns, but the value of this sensitivity risk measure is much lower (0.027) compared to market risk factor (0.595). It may be consequences of windfall profits effect, which was associated with the over-allocation of CO_2 emissions allowances, the ability of firms to pass costs on customers and the profitability of power generation (Joltreau and Sommerfeld, 2017). In the Phase III, the direction of correlation between energy companies returns and the EUA price changes is significant and negative only in the case of Polenergia and Enea. This indicates that ceteris paribus the increase of the EUA prices by 1% may contribute to the decrease in Polenergia and Enea stock prices respectively by 0.016% and 0.030%. This direction of correlation may be explained by the uncertainty caused by such events as: the EU ETS transition into the III phase of functioning and changing rules of EUA allocation, postponing the decision on introducing backloading and tightening the EU environmental and energy policy, which may make more difficult the carbon emission risk management in company. Moreover, in the case of most energy companies idiosyncratic volatility of stock prices was not significantly shaped by the EUA volatility in the Phase II. Enea is an exception from this rule, because empirical results indicate at existence of positive and significant relationship between EUA volatility and Enea stock return volatility (0.0135). Similar effect we can observe in the Phase III, namely EUA volatility is positively related to energy stock return volatility in case of Enea (0.0116) and ZE PAK (0.0029). In the same period, the negative and significant effect of coal and electricity price changes on energy companies stock returns is found for Enea, PGE and Tauron. These findings are in line with Oberndorfer (2009). In the period 2010-2012 the external factors, such as coal volatility and electricity volatility, did not significantly influence on energy stock returns volatility. In case of PGE and Tauron, the impact of electricity price volatility on stocks prices volatility was positive and significant, what might be explained by both the obligation to sell at least 15% of the generated energy on the Polish Power Exchange and a large share of these entities in the electricity generation market in Poland. All estimated parameters assigned to coal price volatility (measurement according to the EU benchmark) in conditional variance equation (3) are statistically insignificant for Polish energy companies. It is worth wondering if these effect may be connected with the government policy directed at obligatory purchases of Polish coal by energy companies, regardless of its market price. In turn, the results presented in Table 2 suggest, that energy companies stock price volatility is positively and significantly related to electricity price volatility in case of Enea (0.0017), PGE (0.0065) and Tauron (0.0013). The results reported in Tables 1-2 suggests that past negative shocks have significantly bigger impact on today's energy companies stock price volatility than past positive shocks in case of PGE (0.345) (Phase II), Enea (0.627) and Kogeneracja (0.178) (Phase III). One may conclude that empirical results may differ not only contingent on the Phase of the EU ETS functioning, but also on the share of energy companies in the power generation market in Poland. Moreover, the impact of EUA price changes on energy companies stock returns and their volatility is statistically insignificant in case of all Respect Index companies.

4. CONCLUSION

In order to compare the influence of CO_2 emission allowance price changes on the energy companies stock prices for two groups: firms included into the Respect Index portfolio and others, we estimated multifactor models with asymmetric power GARCH model specification for conditional variance. Additionally, we added two variables describing coal price volatility, electricity price volatility as possible drivers of carbon allowances price risk. It is worth stressing that the change of CO_2 emission allowances price on the biggest energy corporation PGE SA, which at the same time has the biggest share in the energy sector in the Respect Index portfolio, is statistically insignificant in each analysed Phase of the EU ETS functioning. Thus, it is impossible to evaluate unequivocally on the basis of the conducted analysis the influence of the changes of the CO_2 emission allowances portfolio on the portfolio of energy companies shares. This can be the result of granting by the European Commission derogation for the electricity producers in Poland for the III period of EU ETS functioning, while the majority of the EU electricity producers have to buy CO_2 emission allowances in the auctioning system. It is worth stressing that the investigation of the link between CO_2 emission allowances prices and energy companies stock prices is the key issue taking into account the improvement of carbon emission risk management process in energy companies (Freitas and Silva, 2015). Multifactor models with GARCH structure may be implemented to this purpose, as they provide useful information about the carbon allowances price risk and its impact on energy companies stocks prices. It is interesting to calibrate univariate specification of these models to multivariate version, what will be the subject of further studies.

Making the comparison between different approaches to the carbon emission risk management in Polish electricity companies we noticed that energy companies started to undertake serious actions to carbon mitigation because of two main reasons, increasing carbon-consciousness of stakeholders and economic factors that are stimulated by climate and energy policy rules. Public interest concerning the increase of electricity prices and energy companies' intensions to improve their profitability, were perceived as the drivers for managing their carbon emissions level, after the announcement of the main rules of the EU's climate policy. Moreover, bigger energy corporations, in which the main shareholder is the State Treasury, have not only the well-diversified power generation portfolio, but also are more active in the implementation of eco-innovations into their business. Large energy corporations are more open to participate in scientific research projects aimed at improving the efficiency of energy generation and decarbonisation of the environment, but it needs to stressing that their financial situation is not a barrier in this regard. Energy sector companies more and more often introduce voluntary environmental management system within the framework of improvement their carbon emission risk management system. It is worth stressing that implementation of the environmental management system compliant with the ISO 14001 standard by the energy sector companies is often associated with the endeavoring to productivity improvement, organization's managing improvement and the building of stakeholders trust (Pacana and Ulewicz, 2017).

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