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# THE CLASSIFICATION OF SPOT CONTRACTS FROM POLPX AND EEX

## Introduction

The Polish Power Exchange (POLPX) was started in July 2000. The Day-Ahead Market (DAM) is the first market which was established on POLPX. The DAM is composed of 24-hour markets, quoting one type of hourly contract each. The DAM trading accuracy is PLN 0.01/MWh. The minimum order volume is 0.1 MWh. Trading takes place every day, also on holidays.

The result of the merger of the two German power exchanges in Leipzig and Frankfurt was the establishment the European Energy Exchange AG (EEX) in Leipzig in 2002. On the EEX Spot Markets there is the Day-ahead auction. The minimum volume increment is 0.1 MW for individual hours. The minimum price increment is EUR 0.1 per MWh. Electricity is traded for delivery the following day in 24 hour intervals. The daily auction takes place 7 days a week, year-round, including statutory holidays.

The aim of this paper is to show and compare different levels of risk during a day and during a week on the POLPX and EEX spot markets. Based on Principal Component Analysis (PCA) the classification of contracts from the two power exchanges was made. The classification was made for linear rates of return of 24 contracts listed on the power exchanges from 01.2009 to 24.10.2012. Additionally, the 24 contracts were divided into seven groups dependent on the day of a week. Based on these data sets the classification of risk during a week was made.

## 1. Methodology

The Principal Component Analysis (PCA) is one of the multivariate statistical methods proposed in 1901 by K. Pearson and used in 1933 by H. Hotelling. We use it to study the dependence between variables which describe the multivariate objects. It consists of orthogonal transformation $k$ – dimensional space on new space with the uncorrelated variables. If we note by:
$F = [F_1, F_1, \dots , F_k]^T$ – vector of principal components,
$X = [X_1, X_1, \dots , X_k]^T$ – vector of observational variables,
$A = [a_1, a_1, \dots , a_k]$ – orthogonal and normality matrix.

Then we can express the F vector of transformation:

$$F = A^T X. \tag{1}$$

The PCA consists of calculating the orthogonal and normality matrix $A$. In the first step we calculate vector $a_1$ of matrix $A$ in such a way that $F_1$ has the biggest variance of all principal components. Next we calculate vector $a_2$ that $F_2$ has the biggest variance of the remaining principal components, and $F_1, F_2$ are uncorrelated and so on. We can obtain matrix $A$ from the eigenvalues and eigenvectors of the covariance matrix $C$ of variables F [Trzpiot, Ganczarek, 2006]:

$$a_j = U_j \frac{1}{\sqrt{\lambda_j}} \quad j = 1,...,k , \tag{2}$$

where:
Uj – eigenvector of the covariance matrix $C$,
$\lambda_j$ – eigenvalue of the eigenvector Uj of the covariance matrix $C$.

The $F_j$ principal components have the following properties:

$$D^2(F_1) > D^2(F_2) > ... > D^2(F_k) \tag{3}$$

$$\sum_{j=1}^{k} D^2(F_j) = \sum_{j=1}^{k} D^2(X_j) \tag{4}$$

$$D^2(F_j) = \lambda_j \text{ for } j=1, \dots ,k \tag{5}$$

Equation (4) means that all the observational variables and their volatility are described by all principal components and by eigenvalue (5) [Trzpiot, Ganczarek, 2006].

If $w_j$ denotes the contribution of $F_j$ to the explanation of observational variables, we can write:

$$w_j = \frac{\lambda_j}{\sum_{i=1}^{k} \lambda_i}, j = 1, \dots, k. \tag{6}$$

In the model we use only these principal components which have the biggest part in explaining the variance of observational variables. We often use one of the three criteria to determine the number of principal components. The first one takes into account only these principal components eigenvalues of which are close to one or higher than one. The second criterion eliminates these principal components eigenvalues of which decrease very slight (a scree plot). The third criterion chooses the m-firsts principal components which meet the assumption:

$$\sum_{i=1}^{m} w_i \geq w_0, \tag{7}$$

where $w_0$ is a sufficient number which describes the contribution of $F_j$ to the explanation of observational variables.

Each of the principal components can be interpreted as a source of risk, and the importance of the components is an expression of the volatility of that risk source. The set of the factor loadings, i.e. the elements of matrix $A$, can be interpreted as the original data set corresponding to the source of risk. For energy forward price curves and in financial markets these uncorrelated sources of risk are highly abstract and usually take the form of the following vectors:

- the first factor is called the parallel shift, it governs changes in the overall level of prices;
- second factor is called the slope, it governs the steepness of the curve, it can be interpreted as a change in the overall level of the term structure of convenience yields;
- the third factor is called the curvature, it relates to the possibility of introducing a bend in the curve, that is the front and back go up and the middle goes down, or vice-versa [Blanco, Soronow, Stefiszyn, 2002].

## 2. Empirical analysis

We used PCA to classify the contracts from the POLPX and EEX spot markets. We made four classifications based on the data from 01.2009 to 24.10.2012:

1. Classification of linear daily rates of return of 24 contracts listed on POLPX.
2. Classification of linear daily rates of return of 24 contracts listed on EEX.

3. Classification of linear hourly rates of return of contracts listed on POLPX dependent on the day of a week.
4. Classification of linear hourly rates of return of contracts listed on EEX dependent on the day of a week.

Fig. 1 presents the scree plots. Based on these criteria four principal components were used to describe 24 contracts.

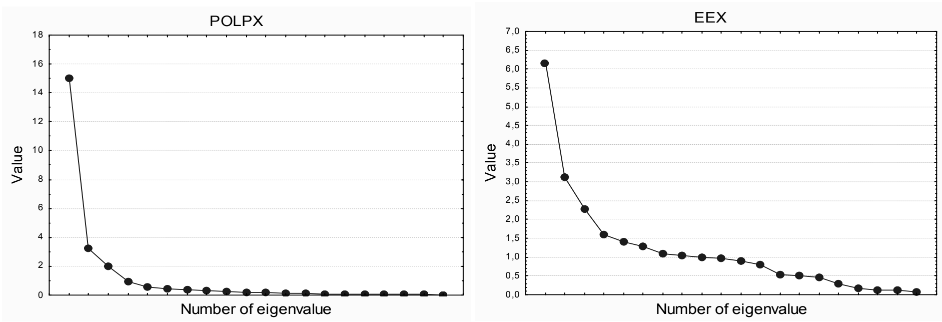


Fig. 1. Scree plot of eigenvalues for 24 contracts listed on POLPX and EEX

Table 1 shows loadings, eigenvalues and contribution of $F_j$ to the explanation of 24 contracts listed on POLPX and EEX.

Table 1

Loadings, eigenvalues and contribution of $F_j$ to the explanation of 24 contracts listed on POLPX and EEX

| X | Factors loadings for 24 contracts listed on POLPX | | | | Factors loadings for 24 contracts listed on EEX | | | |
|---|---|---|---|---|---|---|---|---|
| | F1 | F2 | F3 | F4 | F1 | F2 | F3 | F4 |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 1 | 0.1659 | 0.8263 | 0.0908 | -0.1790 | 0.0274 | -0.0068 | -0.0295 | -0.0880 |
| 2 | 0.1705 | 0.9222 | 0.0929 | 0.0417 | -0.0053 | -0.0330 | -0.0431 | 0.6674 |
| 3 | 0.1725 | 0.9327 | 0.0823 | 0.1584 | 0.0562 | 0.0089 | 0.0094 | -0.7845 |
| 4 | 0.2435 | 0.9054 | 0.0675 | 0.2215 | 0.0129 | 0.0077 | -0.0338 | -0.1161 |
| 5 | 0.3173 | 0.8400 | 0.0444 | 0.3560 | 0.0209 | 0.0026 | -0.0411 | 0.0900 |
| 6 | 0.4568 | 0.5933 | 0.0236 | 0.5778 | -0.0805 | 0.1491 | 0.2917 | 0.4543 |
| 7 | 0.6205 | 0.2521 | -0.0043 | 0.6858 | 0.1691 | -0.0064 | -0.1412 | 0.3707 |
| 8 | 0.6588 | 0.2985 | 0.0275 | 0.6013 | 0.0067 | -0.0288 | -0.1478 | -0.1675 |
| 9 | 0.8183 | 0.2554 | 0.0160 | 0.4240 | 0.1091 | -0.0262 | -0.1139 | 0.1141 |
| 10 | 0.8980 | 0.2365 | 0.0324 | 0.2756 | -0.1337 | 0.0236 | 0.0195 | 0.0679 |
| 11 | 0.9081 | 0.2379 | 0.1188 | 0.2169 | 0.8684 | 0.0547 | 0.1122 | -0.1069 |
| 12 | 0.9072 | 0.2270 | 0.1413 | 0.2004 | 0.9147 | 0.0779 | 0.1539 | -0.0669 |
| 13 | 0.9107 | 0.2101 | 0.1591 | 0.2017 | 0.8917 | 0.1088 | 0.1797 | -0.0561 |
| 14 | 0.9133 | 0.2262 | 0.1751 | 0.1964 | -0.0751 | -0.9883 | 0.0168 | 0.0225 |
| 15 | 0.9045 | 0.2113 | 0.2041 | 0.1948 | 0.1211 | 0.9842 | -0.0143 | -0.0214 |
| 16 | 0.8739 | 0.2418 | 0.2233 | 0.1853 | -0.6124 | -0.4631 | 0.0899 | -0.1423 |
| 17 | 0.8460 | 0.2119 | 0.2830 | 0.1935 | -0.0263 | 0.9734 | 0.0955 | 0.0586 |

Table 1 cont.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| 18 | 0.8069 | 0.1804 | 0.3931 | 0.1519 | 0.8645 | 0.0190 | 0.1928 | 0.1476 |
| 19 | 0.7126 | 0.1619 | 0.5582 | 0.1416 | 0.7961 | 0.0070 | 0.4445 | 0.1403 |
| 20 | 0.5772 | 0.1061 | 0.6954 | 0.1455 | 0.5454 | -0.0038 | 0.6759 | 0.0979 |
| 21 | 0.3394 | 0.0781 | 0.8546 | 0.0972 | 0.3532 | 0.0279 | 0.8264 | 0.1863 |
| 22 | -0.0427 | 0.0776 | 0.8666 | -0.0152 | 0.2096 | 0.0064 | 0.8966 | 0.0573 |
| 23 | 0.4870 | 0.0613 | 0.4524 | 0.5794 | 0.0259 | 0.0178 | 0.8874 | 0.0875 |
| 24 | 0.5001 | 0.0290 | 0.3793 | 0.5295 | 0.1080 | -0.0442 | 0.6473 | -0.2057 |
| $\lambda_j$ | 10.4551 | 4.9924 | 3.0740 | 2.6223 | 4.7109 | 3.1572 | 3.6170 | 1.6625 |
| $w_j$ | 0.4356 | 0.2080 | 0.1281 | 0.1093 | 0.1963 | 0.1315 | 0.1507 | 0.0693 |
| $\sum_{j=1}^{m} w_j$ | 0.4356 | 0.6436 | 0.7717 | 0.8810 | 0.1963 | 0.3278 | 0.4785 | 0.5478 |

On POLPX four components explain 88.1% volatility of 24 contracts (Tab. 1). The first component represents the volatility of contracts during aday: from 9.00 to19.00 hours (43.56% volatility of 24 contracts). The second one represents the volatility of contracts during a night: from 1.00 to 6.00 hours (20.80% volatility of 24 contracts). The third one represents the volatility of contracts during an evening: from 20.00 to 22.00 hours (12.81% volatility of 24 contracts). The fo-urth one represents the volatility of contracts during an early morning: from 7.00 to 8.00 hours (10.93% volatility of 24 contracts). Fig. 2 presents 24 contracts from POLPX in the symmetrical factorial design. Based on Fig. 2 we can divide contracts into or four groups: day contracts (from 7 to 24 without 22), night con-tracts (from 1 to 5), contracts in hour 6 and contracts in hour 22.

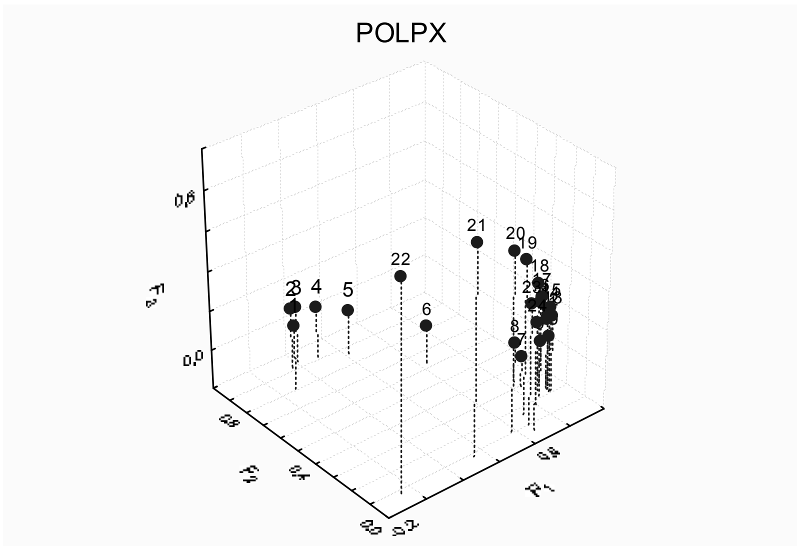


Fig. 2. The 24 contracts from POLPX in the symmetrical three factorial design

On EEX four components explain 54.78% of the volatility of 24 contracts (Tab. 1). Comparing this result with the result on POLPX, where two components explain 64.36% of the volatility of 24 contracts we can say that PCA is not a very good method to describe the volatility of contracts on EEX. This low explanation rate of PCA on the data on EEX is a consequence of correlations between contracts (Appendix: Table A3, Table A4). On POLPX we can observe a very significant linear correlation between 24 contracts, on EEX correlations are very low or even do not exist at all. The first and second components represent the volatility of contracts during aday: from 11.00 to19.00 hours (32.78% volatility of 24 contracts). The third one represents the volatility of contracts during an evening: from 20.00 to 24.00 hours (15.07% volatility of 24 contracts). The fourth one represents the volatility of contracts during a night: at 2.00 and 3.00 hours (6.93 % volatility of 24 contracts). Fig. 3 presents 24 contracts from EEX in the symmetrical factorial design. Based on Fig. 3 we can divide contracts into six groups: contracts from 19.00 to 24.00, contracts from 11.00 to 23.00, contracts from 1.00 to 10.00, contracts at hours 6.00, 15.00, 17.00 and the last two single groups of contracts at hour 14.00 and 16.00.

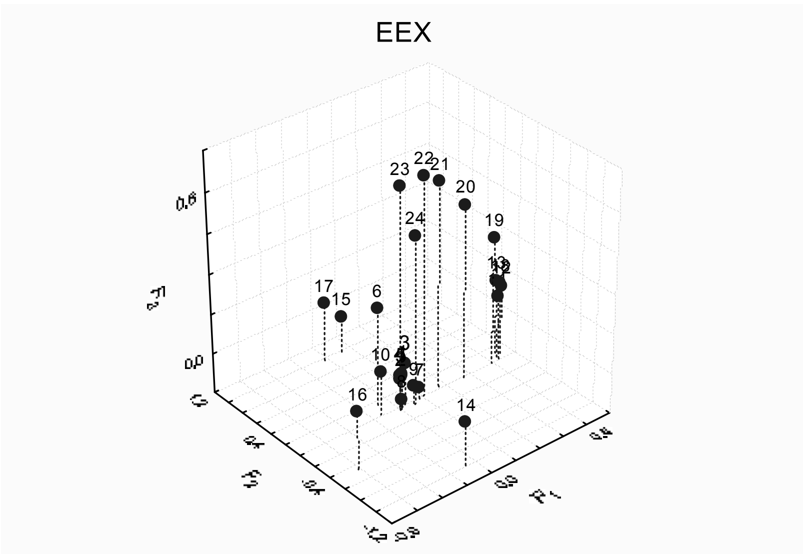


Fig. 3. The 24 contracts from EEX in the symmetrical three factorial design.

In the next step we presented the classification of linear hourly rates of return of contracts listed on POLPX and EEX dependent on the day of a week. Fig. 4 shows the scree plots of eigenvalues for 7 daily rates of return listed on POLPX and EEX. Based on these criteria two principal components were used to describe 7 days.

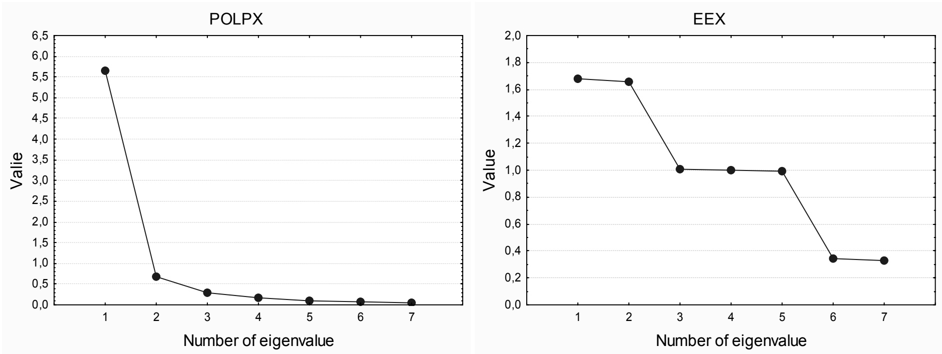


Fig. 4. Scree plot of eigenvalues for 7 daily rates of return on the contracts listed POLPX and EEX

Table 2 shows loadings, eigenvalues and contribution of $F_j$ for volatility of prices on POLPX and EEX during a week.

Table 2

Loadings, eigenvalues and contribution of $F_j$ to the explanation of 7 daily rates of return on the contracts listed on POLPX and EEX

| X | Factors loadings for 7 daily rates of return on the contracts listed on POLPX | | Factors loadings for 7 daily rates of return on the contracts listed on EEX | |
|---|---|---|---|---|
| | F1 | F2 | F1 | F2 |
| 1 | 0.8669 | 0.3088 | 0.9149 | -0.0074 |
| 2 | 0.9068 | 0.3342 | 0.0197 | 0.9104 |
| 3 | 0.9043 | 0.3671 | 0.0125 | 0.9102 |
| 4 | 0.8781 | 0.3983 | 0.9147 | -0.0161 |
| 5 | 0.8436 | 0.4260 | -0.0013 | 0.0177 |
| 6 | 0.5074 | 0.7750 | 0.0003 | 0.0153 |
| 7 | 0.2792 | 0.9174 | -0.0006 | 0.0111 |
| $\lambda_j$ | 4.2096 | 2.1242 | 1.6743 | 1.6581 |
| $w_j$ | 0.6014 | 0.3035 | 0.2392 | 0.2369 |
| $\sum_{j=1}^{m} w_j$ | 0.6014 | 0.9048 | 0.2392 | 0.4761 |

On POLPX two components explain 90.48% volatility of prices during a week (Tab. 2). The first component represents the volatility of weekdays. The second one represents the volatility of contracts at the weekend. On EEX two components explain 47.61% volatility of prices during a week (Tab. 2). The first component represents the volatility of Monday and Thursday. The second one represents the volatility of Tuesday and Wednesday. Comparing this result with the result on POLPX, we can say that PCA is not a very good method to describe the volatility of prices during a week on EEX. This low explanation rate of PCA on the data on EEX is a consequence of correlations between contracts (Appendix: Tab. A1, Tab. A2). On POLPX we can observe a very significant linear correlation between rates of return on the contracts listed on each of 7 days during a week, on EEX correlations are very low or even do not exist at all. Fig. 5 presents rates of return for each of 7 days during a week in the symmetrical factorial design on POLPX and EEX. Based on Fig. 5 for POLPX we can divide contracts into two groups: weekdays and weekends. Based on Fig. 5 for EEX we can divide contracts into three groups: Monday and Thursday, Tuesday and Wednesday and the weekend.

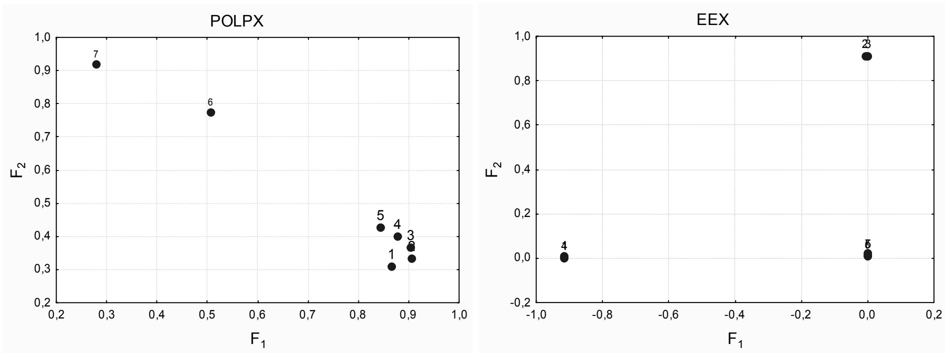


Fig. 5. The 7 daily rates of return from POLPX and EEX in the symmetrical two factorial design

## Conclusion

Based on PCA for volatility of contracts on electric energy listed from 01.2009 to 24.10.2012, we can say that the volatility of contracts on the Polish Power Exchange is correlated with each of 24 contracts and with the volatility of rates of return during a week. The PCA shows these dependences very clearly. In the same time period on EEX the correlation between 24 contracts and between volatility of rates of return during a week does not exist. The PCA is not an appropriate method for risk classification on EEX.

## Literature

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## Appendix

In Appendix the correlation matrix of daily rates of return for 24 contracts and hourly rates of return in every day during a week from POLPX and EEX were presented. Let $\hat{\rho}$ means correlation coefficient between two contracts. The white cells means that $\left|\hat{\rho}\right| \le 0{,}3$. The light grey cells mean that $\left|\hat{\rho}\right| \le 0{,}7$. The dim grey cells mean that $\left|\hat{\rho}\right| > 0{,}7$.

Table A1

Correlation matrix of rates of return of electric energy prices in w week on POLPX

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1 | 1,00 | 0,90 | 0,86 | 0,83 | 0,80 | 0,64 | 0,57 |
| 2 | 0,90 | 1,00 | 0,94 | 0,89 | 0,86 | 0,70 | 0,58 |
| 3 | 0,86 | 0,94 | 1,00 | 0,95 | 0,91 | 0,74 | 0,59 |
| 4 | 0,83 | 0,89 | 0,95 | 1,00 | 0,93 | 0,75 | 0,60 |
| 5 | 0,80 | 0,86 | 0,91 | 0,93 | 1,00 | 0,77 | 0,60 |
| 6 | 0,64 | 0,70 | 0,74 | 0,75 | 0,77 | 1,00 | 0,75 |
| 7 | 0,57 | 0,58 | 0,59 | 0,60 | 0,60 | 0,75 | 1,00 |

Table A2

Correlation matrix of rates of return of electric energy prices in w week on EEX

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1 | 1,0000 | 0,0112 | 0,0032 | 0,6740 | 0,0001 | 0,0000 | -0,0005 |
| 2 | 0,0112 | 1,0000 | 0,6581 | 0,0021 | 0,0115 | 0,0095 | 0,0083 |
| 3 | 0,0032 | 0,6581 | 1,0000 | -0,0004 | 0,0013 | 0,0016 | -0,0001 |
| 4 | 0,6740 | 0,0021 | -0,0004 | 1,0000 | -0,0012 | 0,0001 | 0,0000 |
| 5 | 0,0001 | 0,0115 | 0,0013 | -0,0012 | 1,0000 | 0,0016 | -0,0039 |
| 6 | 0,0000 | 0,0095 | 0,0016 | 0,0001 | 0,0016 | 1,0000 | 0,0001 |
| 7 | -0,0005 | 0,0083 | -0,0001 | 0,0000 | -0,0039 | 0,0001 | 1,0000 |

Table A3

Correlation matrix of daily rates of return for 24 contracts from POLPX

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | | | | | | | | | | | | | |
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| 22 | | | | | | | | | | | | | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | | | | | | | | | | | | | |
| 24 | | | | | | | | | | | | | | | | | | | | | | | | |

Table A4

Correlation matrix of daily rates of return for 24 contracts from EEX

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | | | | | | | | | | | | | |
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| 13 | | | | | | | | | | | | | | | | | | | | | | | | |
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| 24 | | | | | | | | | | | | | | | | | | | | | | | | |

## THE CLASSIFICATION OF SPOT CONTRACTS FROM POLPX AND EEX

### Summary

The aim of this paper is to show and compare different levels of risk during a day and during a week on spot markets from the Polish Power Exchange (POLPX) and the European Energy Exchange (EEX). Based on Principal Component Analysis (PCA) the classification of contracts from the two power exchanges was made. The classification was made for linear rates of return of 24 contracts listed on the power exchanges from 01.2009 to 24.10.2012. Additionally, the 24 contracts were divided into seven groups dependent on the day of a week. Based on these data sets the classification of risk during a week was made.