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Barbara Glensk[*]
Alicja Ganczarek-Gamrot[**]
Grażyna Trzpiot[**]

PORTFOLIO ANALYSIS ON POLISH POWER EXCHANGE AND EUROPEAN ENERGY EXCHANGE

Abstract

The aim of this paper is a comparative analysis of contract electric energy portfolios at Polish Power Exchange (POLPX) and European Energy Exchange (EEX) spot markets. The multi-criteria approach proposed in this paper is based on minimization of the Conditional Value at Risk with the confidence level 0.95 and maximization of portfolio rates of return. The analyzed portfolios have been constructed independently for each power exchange (for investors who are interested to invest on one market only), as well as for POLEX and EEX together (for investors who invest on more than one market) with two criteria.

Keywords: Portfolio analysis, Conditional Value at Risk (CVaR), electric energy spot markets

1 Introduction

The Polish Power Exchange (POLPX) was opened in July 2000. Investors on POLPX may participate in the Day Ahead Market (DAM, spot market), the Commodity Derivatives Market (CDM, future market), the Electricity Auctions, the Property Right Market, the Emission Allowances Market (CO2 spot) and the Intraday Market. All these markets differ with respect to the investment horizon and the commodity traded.

As the result of the merger of the two German power exchanges in Leipzig and Frankfurt the European Energy Exchange AG (EEX) in Leipzig was

[*] Institute for Future Energy Consumer Needs and Behavior, E.ON Energy Research Center, RWTH Aachen University, email: *BGlensk@eonerc.rwth-aachen.de*
[**] Department of Demography and Economic Statistics, University of Economics in Katowice, 1 Maja 50, 40-287 Katowice, Poland e-mail: *alicja.ganczarek-gamrot@ue.katowice.pl,* e-mail: *grazyna.trzpiot@ue.katowice.pl*

established in 2002. This is one of the European trading and clearing platforms for energy and energy-related products, such as natural gas, CO_2 emission allowances and coal. The EEX consists of three sub-markets (EEX Spot Markets, EEX Power Derivatives and EEX Derivatives Markets) and one Joint Venture (EPEX Spot Market). Moreover, EEX is trying to become the leader among the European Energy Exchanges assuming an active role in the development and integration process of the European market.

The aim of this paper is a comparative analysis of risk on electric energy spot markets. In this paper we propose portfolios based on linear daily rates of return of prices noted on POLPX and EEX from 1st January 2009 to 24th October 2012. We compare risk on these portfolios built independently on two markets and the portfolios of contracts from POLPX and EEX together.

The analyzed portfolios are constructed based on two criteria: minimization of the Conditional Value at Risk (CVaR) with the confidence level 0.95 and maximization of the portfolio rates of return.

2 Methodology

When we make financial decisions, at the same time we take the risk. If we want to estimate the future risk we must measure it. There are many different kinds of risk measures, one of them is downside risk. In these measures we used a well known quantile downside risk measure such as: Value-at-Risk (VaR) and Conditional Value-at-Risk (CVaR) (Blanco, 1998; Jajuga and Jajuga, 1998; Weron and Weron 2000; Heilpern, 2011):

VaR is defined as such loss of value, which is not exceeded with the given probability α at the given time period Δt, and given by the formula:

$$\mathrm{P}(W_{t+\Delta t} \leq W_t - VaR_\alpha(W)) = \alpha \tag{1}$$

where:

W_t - is a present value,

$W_{t+\Delta t}$ - is a random variable, value at the end of duration of investment.

Equation (1) describes VaR_α for short position. VaR_α answers the question: How much money can we lose over time period Δt with probability $1-\alpha$? The VaR quantity represents the maximum possible loss, which is not exceeded with the probability α.

For linear rates of return VaR_α we can write as a percentile of the order α of rates of return for short position:

$$\mathrm{P}(R_t \leq VaR_\alpha(R)) = \alpha \tag{2}$$

and for long position:

$$\mathrm{P}(R_t \leq VaR_{1-\alpha}(R)) = 1-\alpha \tag{3}$$

where:

$R_t = \dfrac{P_t - P_{t-1}}{P_{t-1}}$ - is a linear rate of return of contract

P_t, P_{t-1} are the prices.

Without the assumption of a normal distribution of the rate of return, VaR is a problematic risk measure because it is not coherent (Artzner et al., 1999). It means that VaR for a diversified portfolio can be greater than the sum of VaR values of individual assets. In this sense, the measure, which does not meet the subadditivity requirement, cannot be the basis for portfolio diversification and optimization (Rockafellar and Uryasev, 2000; Rockafellar and Uryasev, 2002). In contrast, CVaR has better properties than VaR. The CVaR quantity is the conditional expected loss given the loss strictly exceeds its VaR. In literature CVaR is also called Expected Shortfall (ES) (Ogryczak and Ruszczyński, 2002; Heilpern, 2011). For short position we can write:

$$CVaR_\alpha(R) = ES_\alpha(R) = E\{R \mid R \geq VaR_\alpha(R)\}. \tag{4}$$

For long position we can write

$$CVaR_{1-\alpha}(R) = ES_{1-\alpha}(R) = E\{R \mid R \leq VaR_{1-\alpha}(R)\}. \tag{5}$$

CVaR is defined as the mean of the quantile of worst realizations. The definitions ensure that VaR is never greater than CVaR, so portfolios with low CVaR must have low VaR as well. Pflug (2000) proved that CVaR is a coherent risk measure with the following properties: transition-equivariant, positively homogeneous, convex, monotonic, with stochastic dominance of order 1, and with monotonic dominance of order 2. (Pflug, 2000; Rockafellar and Uryasev, 2000). These properties let us use CVaR in portfolio analysis. Moreover, various numerical experiments and studies considering portfolio optimization with CVaR point out that the minimization of CVaR leads to optimal solutions in terms of VaR (Uryasev, 2000; Rockafellar and Uryasev, 2002).

The portfolio selection model proposed in this paper is based on the two criteria "mean-variance" portfolio problem analyzed by Steuer et al. (2006):

$$\begin{aligned} &\min\{x^T \textstyle\sum x\} \\ &\max \mu^T x \\ &x \in S \end{aligned} \tag{6}$$

which regarding CVaR – downside risk measure for short position is given as follows:

$$\begin{aligned}&\min \boldsymbol{CVaR}_{\alpha}\\&\max \mu^{T} x\\&x \in S\end{aligned} \qquad (7)$$

and for long position:

$$\begin{aligned}&\min \boldsymbol{CVaR}_{1-\alpha}\\&\max \mu^{T} x\\&x \in S\end{aligned} \qquad (8)$$

where:

$\boldsymbol{CVaR}_{\alpha}$ - *Conditional Value-at-Risk* for portfolio for short position,

$\boldsymbol{CVaR}_{1-\alpha}$ - *Conditional Value-at-Risk* for portfolio for long position,

x - vector of portfolio weights,

μ - vector of contracts means belonging to portfolio,

S - set of acceptable results

$\sum$ - covariance matrix.

Using results of Steuer et al. (2011) the problems (7)-(8) may be expressed in the following form for short position:

$$\begin{aligned}&\min \left| \boldsymbol{CVaR}_{\alpha} - \mu^{T} x \right|\\&x_{\min} \le x_i \le x_{\max}\\&\sum_{i=1}^{m} x_i = 1\end{aligned} \qquad (9)$$

and for long position:

$$\begin{aligned}&\min \left| \boldsymbol{CVaR}_{1-\alpha} - \mu^{T} x \right|\\&x_{\min} \le x_i \le x_{\max}\\&\sum_{i=1}^{m} x_i = 1\end{aligned} \qquad (10)$$

In Figure 1 the distance between CVaR calculated for portfolio rate of return and expected rates of return of portfolio is presented.

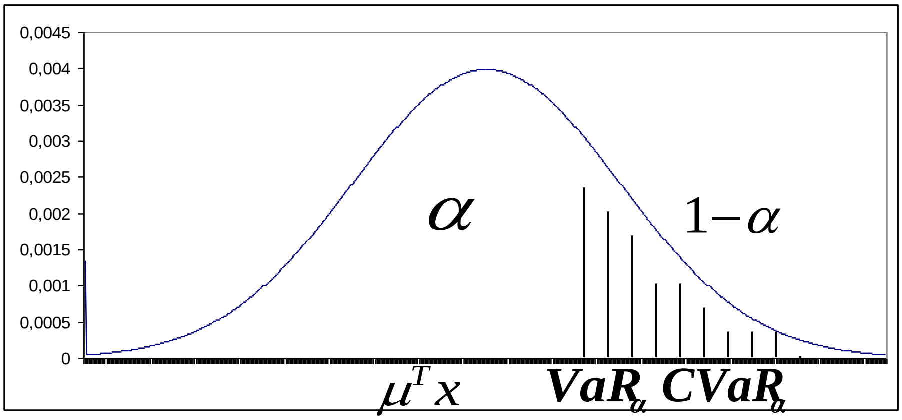

Figure 1. Distribution of rates of return of portfolio

3 Empirical analysis

Investors from spot energy markets make trading decisions with one day horizon of investment. So, to build portfolios from POLPX and EEX we consider daily rates of return of prices from 1st January 2009 to 24th October 2012. We estimate *VaR* and *CVaR* using the historical simulation method with $\alpha = 0.95$. Moreover, because of negative energy prices on EEX, linear rates of return have been applied. In both analyzed markets investors can buy and sell electric energy in 24 independent contracts. Parameters of contract distribution of linear rates of return from spot markets are presented in Table 1. Distribution of contracts is characterized by very high volatility, asymmetry and is leptokurtic. In such situations, the classical risk measures such as variance, which is very sensitive to extreme values and asymmetry, is not appropriate. Furthermore, the values of percentiles and standard deviation of contracts observed on spot markets show that volatility of prices on POLPX is much lower than that on EEX.

In the first step of our risk analysis we built portfolios independently on POLPX and EEX. In table 2 we presented portfolios for investors who take up long position on POLPX. Based on problem (10) we built three different portfolios. In the first portfolio we used restriction $0 \le x_i \le 1$ for portfolio weights. This portfolio consists only of night contracts (see Table 2, and Figure 2). In the next two portfolios the real demand for electric energy in respective hours of the day was taken into consideration ($0 \le x_i \le x_{\max}$). In the second portfolio x_{max} was assumed to be equal to the real demand observed on POLPX for the contract in the studied period, augmented by 5%. In the third portfolio contracts are augmented by 2.5%. Based on these portfolios we can say that investors shouldn't buy electric energy in the hours 7-11, 14 and 17 (compare Figure 2 and Table 2).

Table 1

Distribution parameters of rates of return of contracts on spot market

Contracts	POLPX						EEX					
	Mean	Percentyl 5%	Percentyl 95%	Stand. dev.	Skewness	Kurtozis	Mean	Percentyl 5%	Percentyl 95%	Stand. dev.	Skewness	Kurtosis
1	0.002	-0.09	0.09	0.06	1.46	19.17	0.247	-0.38	0.48	15.70	25.19	987.87
2	0.003	-0.10	0.11	0.07	0.21	5.53	-2.671	-0.52	0.70	83.21	-26.41	754.31
3	0.003	-0.11	0.13	0.07	0.22	5.15	1.780	-0.63	1.04	94.13	29.01	1063.26
4	0.004	-0.12	0.12	0.08	0.13	4.77	-1.510	-0.75	1.46	61.72	-25.02	839.34
5	0.004	-0.13	0.14	0.09	0.51	5.28	0.794	-0.66	1.40	34.26	-5.23	383.43
6	0.007	-0.15	0.20	0.12	1.52	8.64	1.776	-0.63	1.18	83.18	33.42	1215.64
7	0.017	-0.21	0.39	0.20	2.28	8.86	-6.285	-0.77	2.26	144.85	-14.43	286.98
8	0.013	-0.19	0.34	0.17	2.20	9.89	-3.792	-0.62	1.98	101.87	-18.37	458.77
9	0.012	-0.19	0.35	0.16	2.12	11.20	1.062	-0.47	1.34	76.54	23.18	941.68
10	0.01	-0.17	0.31	0.14	1.91	10.86	-0.944	-0.37	0.89	40.03	-37.10	1381.80
11	0.007	-0.15	0.25	0.12	1.39	5.94	0.054	-0.35	0.72	0.42	4.29	32.75
12	0.007	-0.15	0.25	0.12	1.29	5.25	0.041	-0.31	0.60	0.34	4.26	43.19
13	0.007	-0.15	0.23	0.11	1.26	4.99	0.041	-0.32	0.53	0.35	4.36	41.31
14	0.006	-0.15	0.23	0.11	1.12	4.03	-1.007	-0.36	0.75	39.84	-37.30	1391.63
15	0.005	-0.13	0.21	0.10	1.22	3.84	0.757	-0.38	0.90	24.62	37.21	1386.89
16	0.005	-0.12	0.19	0.10	1.32	6.23	-3.779	-0.40	0.93	95.60	-28.04	834.61
17	0.006	-0.13	0.21	0.11	1.48	8.09	0.558	-0.38	0.85	17.18	32.86	1160.54
18	0.006	-0.12	0.20	0.11	1.40	11.77	0.049	-0.32	0.62	0.54	19.27	552.08
19	0.004	-0.11	0.15	0.09	1.08	11.67	0.025	-0.26	0.47	0.27	6.30	102.49
20	0.004	-0.10	0.13	0.08	0.66	10.87	0.017	-0.24	0.35	0.20	2.24	13.34
21	0.003	-0.09	0.11	0.07	1.04	14.80	0.014	-0.22	0.31	0.19	3.36	36.56
22	0.002	-0.08	0.09	0.06	1.36	18.94	0.011	-0.20	0.27	0.15	1.58	8.00
23	0.001	-0.07	0.09	0.05	0.95	6.59	0.011	-0.20	0.24	0.16	2.89	26.03
24	0.002	-0.08	0.10	0.06	5.07	89.16	0.016	-0.25	0.32	0.30	5.31	99.25

In Table 3 we presented portfolios for an investor opening long positions on EEX. Based on problem (10) we built once again three different portfolios. For the portfolio with restriction $0 \le x_i \le 1$ we obtained portfolios without contracts in the hours 1, 2, 8 and 9 (see Table 3 and Figure 3). For every hour during a day we built two portfolios ($0 \le x_i \le x_{\max}$) under the same constraint as for POLPX. Based on these portfolios we can say that investors shouldn't buy electric energy in the hours 1, 6 and 9 (compare Table 3 and Figure 3).

If we compare risk measures by $CVaR_{0,95}$ we can see that the risk on EEX is much higher than the risk on POLPX.

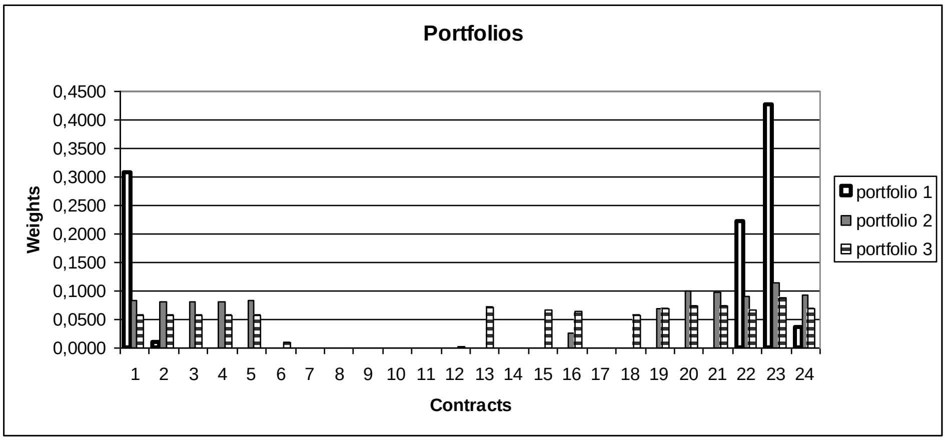

Figure 2. Weights of contracts in portfolios from POLPX

In the next step of the analysis the portfolios based on 48 contracts from POLPX and EEX have been built. Table 4 and Figure 4-6 present results of the optimization problem (10). In general, the risk on EEX is greater than the risk on POLPX, so weights of contracts from POLPX are greater than weights of contracts from EEX, especially for night and early morning hours from 1 to 9. For hours during the day differences between weights are not very significant. Investors who want to buy electric energy in the hour 24 should choose EEX.

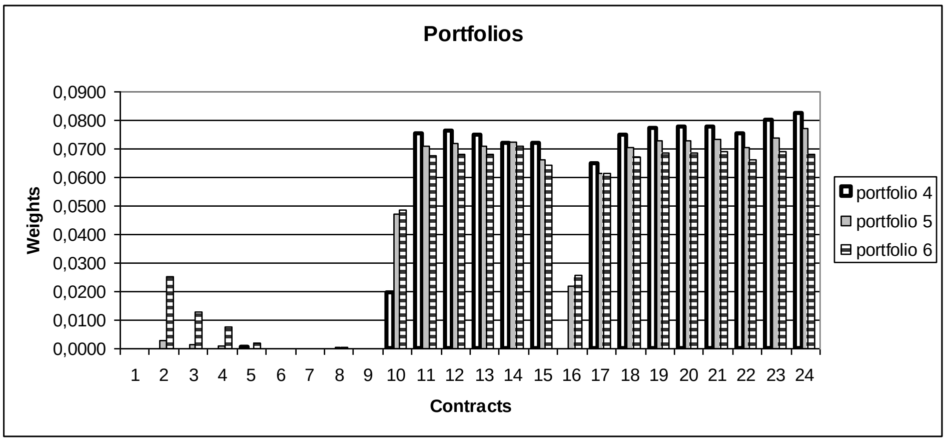

Figure 3. Weights of contracts in portfolios from EEX

Table 2

Portfolios on POLPX

Contracts	Portfolio 1			Portfolio 2			Portfolio 3		
	x	x_{min}	x_{max}	x	x_{min}	x_{max}	x	x_{min}	x_{max}
1	0.3078	0	1	0.0833	0	0.0833	0.0583	0	0.0583
2	0.0104	0	1	0.0817	0	0.0817	0.0567	0	0.0567
3	0	0	1	0.0816	0	0.0816	0.0566	0	0.0566
4	0	0	1	0.0818	0	0.0818	0.0568	0	0.0568
5	0	0	1	0.0824	0	0.0824	0.0574	0	0.0574
6	0	0	1	0	0	0.0835	0.0103	0	0.0585
7	0	0	1	0	0	0.0976	0	0	0.0726
8	0	0	1	0	0	0.0859	0	0	0.0609
9	0	0	1	0	0	0.0904	0	0	0.0654
10	0	0	1	0	0	0.0939	0	0	0.0689
11	0	0	1	0	0	0.0951	0	0	0.0701
12	0	0	1	0	0	0.0969	0.0030	0	0.0719
13	0	0	1	0	0	0.0962	0.0712	0	0.0712
14	0	0	1	0	0	0.0958	0	0	0.0708
15	0	0	1	0	0	0.0922	0.0672	0	0.0672
16	0	0	1	0.0252	0	0.0892	0.0642	0	0.0642
17	0	0	1	0	0	0.0900	0	0	0.0650
18	0	0	1	0	0	0.0919	0.0577	0	0.0669
19	0	0	1	0.0685	0	0.0950	0.0700	0	0.0700
20	0	0	1	0.0989	0	0.0989	0.0739	0	0.0739
21	0	0	1	0.0985	0	0.0985	0.0735	0	0.0735
22	0.2215	0	1	0.0912	0	0.0912	0.0662	0	0.0662
23	0.4256	0	1	0.1137	0	0.1137	0.0887	0	0.0887
24	0.0347	0	1	0.0933	0	0.0933	0.0683	0	0.0683
Objective (6)	0.0934			0.1277			0.1595		
Mmean	0.0016			0.0028			0.0036		
VaR	0.0625			0.0852			0.1115		
CVaR	0.0950			0.1305			0.1630		
Std. Deviation	0.0369			0.0503			0.0605		

In portfolio 7 the restriction $0 \leq x_i \leq 1$ for portfolio weights was used similar to portfolio 1 (for POLPX) and portfolio 4 (for EEX). For portfolios 8 and 9 x_{max} was assumed in the same way as for the portfolios constructed earlier for POLPX and EEX.

Table 3

Portfolios on EEX

Contracts	Portfolio 4			Portfolio 5			Portfolio 6		
	x	x_{min}	x_{max}	x	x_{min}	x_{max}	x	x_{min}	x_{max}
1	0	0	1	0	0	0.0833	0	0	0.0583
2	0	0	1	0.0030	0	0.0817	0.0252	0	0.0567
3	0.0001	0	1	0.0016	0	0.0816	0.0130	0	0.0566
4	0.0002	0	1	0.0007	0	0.0818	0.0077	0	0.0568
5	0.0005	0	1	0	0	0.0824	0.0017	0	0.0574
6	0.0002	0	1	0	0	0.0835	0	0	0.0585
7	0.0002	0	1	0.0002	0	0.0976	0.0001	0	0.0726
8	0	0	1	0.0005	0	0.0859	0.0006	0	0.0609
9	0	0	1	0	0	0.0904	0	0	0.0654
10	0.0196	0	1	0.0470	0	0.0939	0.0485	0	0.0689
11	0.0754	0	1	0.0711	0	0.0951	0.0678	0	0.0701
12	0.0760	0	1	0.0717	0	0.0969	0.0681	0	0.0719
13	0.0748	0	1	0.0710	0	0.0962	0.0681	0	0.0712
14	0.0718	0	1	0.0724	0	0.0958	0.0708	0	0.0708
15	0.0719	0	1	0.0661	0	0.0922	0.0645	0	0.0672
16	0.0001	0	1	0.0220	0	0.0892	0.0259	0	0.0642
17	0.0649	0	1	0.0614	0	0.0900	0.0612	0	0.0650
18	0.0749	0	1	0.0705	0	0.0919	0.0669	0	0.0669
19	0.0770	0	1	0.0726	0	0.0950	0.0686	0	0.0700
20	0.0775	0	1	0.0731	0	0.0989	0.0688	0	0.0739
21	0.0777	0	1	0.0733	0	0.0985	0.0689	0	0.0735
22	0.0751	0	1	0.0707	0	0.0912	0.0662	0	0.0662
23	0.0798	0	1	0.0738	0	0.1137	0.0692	0	0.0887
24	0.0823	0	1	0.0770	0	0.0933	0.0683	0	0.0683
Objective (6)	0.9805			1.1478			1.4198		
Mean	0.0199			-0.1057			-0.1706		
VaR	0.4453			0.4879			0.5600		
CVaR	1.0004			1.0421			1.2491		
Std. Deviation	0.8526			2.9270			3.7443		

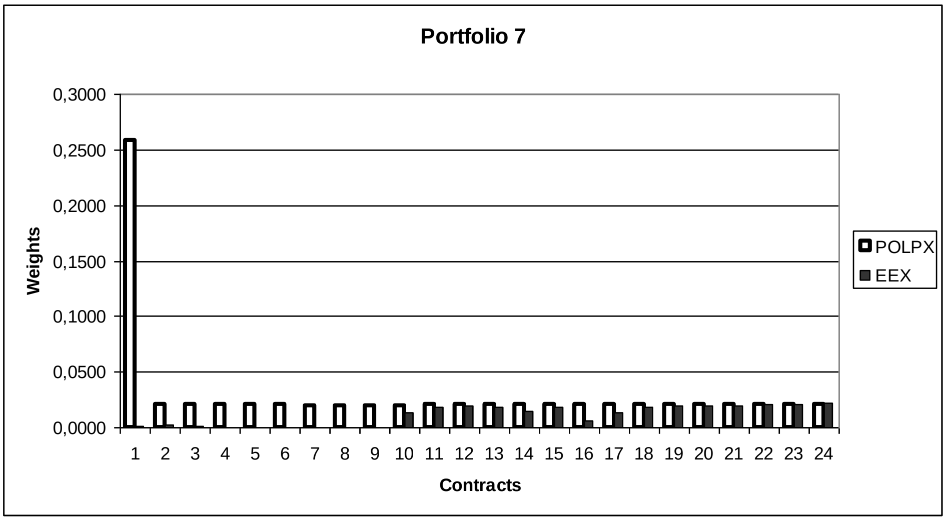

Figure 4. Weights of contracts in portfolio from POLPX and EEX (with the restriction $0 \le x_i \le 1$)

The negative value of portfolios return for POLPX and EEX together (see Table 4) as well as for EEX (see Table 3) can result from negative electricity prices observed on EEX[1].

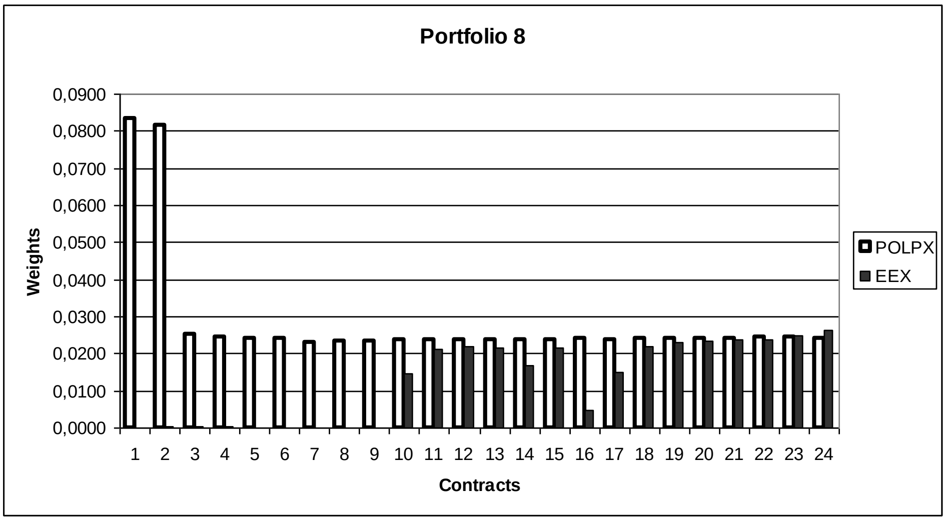

Figure 5. Weights of contracts in portfolio from POLPX and EEX (with the restriction $0 \le x_i \le x_{\max}$ argumented by 5%)

[1] The negative electricity prices ware first observed in 2009 on EEX as a result of demand and supply changes which come independently from price.

Table 4

Portfolios on POLPX and EEX

Contracts	Portfolio 7			Portfolio 8			Portfolio 9		
	POLPX	EEX	x_{max}	POLPX	EEX	x_{max}	POLPX	EEX	x_{max}
1	0.2589	0.0010	1	0.0833	0.0000	0.0833	0.0583	0.0000	0.0583
2	0.0208	0.0022	1	0.0817	0.0004	0.0817	0.0567	0.0000	0.0567
3	0.0207	0.0011	1	0.0252	0.0002	0.0816	0.0566	0.0000	0.0566
4	0.0207	0.0000	1	0.0244	0.0004	0.0818	0.0290	0.0012	0.0568
5	0.0206	0.0000	1	0.0243	0.0000	0.0824	0.0248	0.0000	0.0574
6	0.0204	0.0000	1	0.0240	0.0000	0.0835	0.0245	0.0000	0.0585
7	0.0199	0.0001	1	0.0232	0.0002	0.0976	0.0237	0.0001	0.0726
8	0.0200	0.0000	1	0.0234	0.0001	0.0859	0.0239	0.0002	0.0609
9	0.0201	0.0000	1	0.0235	0.0000	0.0904	0.0240	0.0000	0.0654
10	0.0202	0.0139	1	0.0237	0.0147	0.0939	0.0242	0.0144	0.0689
11	0.0203	0.0185	1	0.0239	0.0213	0.0951	0.0244	0.0217	0.0701
12	0.0203	0.0190	1	0.0239	0.0220	0.0969	0.0244	0.0224	0.0719
13	0.0204	0.0188	1	0.0239	0.0217	0.0962	0.0244	0.0222	0.0712
14	0.0203	0.0152	1	0.0239	0.0169	0.0958	0.0244	0.0169	0.0708
15	0.0204	0.0189	1	0.0239	0.0216	0.0922	0.0245	0.0223	0.0672
16	0.0204	0.0063	1	0.0240	0.0048	0.0892	0.0245	0.0040	0.0642
17	0.0204	0.0139	1	0.0239	0.0148	0.0900	0.0244	0.0145	0.0650
18	0.0204	0.0189	1	0.0240	0.0220	0.0919	0.0245	0.0223	0.0669
19	0.0205	0.0196	1	0.0241	0.0229	0.0950	0.0246	0.0233	0.0700
20	0.0206	0.0200	1	0.0242	0.0234	0.0989	0.0247	0.0239	0.0739
21	0.0206	0.0202	1	0.0243	0.0237	0.0985	0.0249	0.0242	0.0735
22	0.0208	0.0204	1	0.0245	0.0240	0.0912	0.0251	0.0245	0.0662
23	0.0207	0.0210	1	0.0243	0.0250	0.1137	0.0249	0.0253	0.0887
24	0.0206	0.0220	1	0.0243	0.0262	0.0933	0.0248	0.0262	0.0683
Objective (6)	0.3974			0.4129			0.4137		
Mean	-0.0258			-0.0169			-0.0140		
VaR	0.2144			0.2429			0.2476		
CVaR	0.3716			0.3960			0.3997		
Std. Deviation	0.7980			0.7143			0.6682		

4 Conclusion

Concluding, the risk of price changes on EEX is much greater than the analogous risk on POLPX, but, based on two criteria to build the portfolio, the investor should sell electricity on EEX too. For investors, contracts in the night and early morning hours on POLPX are more attractive, but for odd hours contracts on two spot markets give a very similar distance between risk and profit.

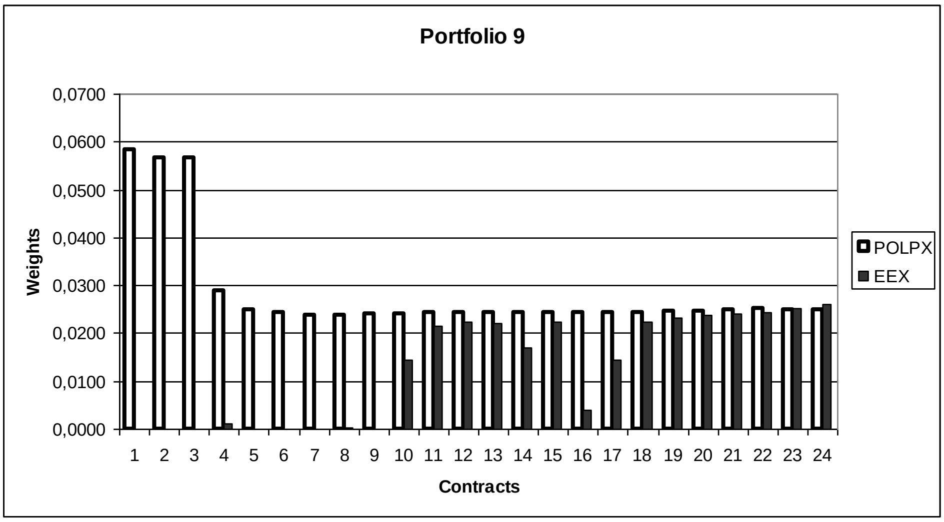

Figure 6. Weights of contracts in portfolio from POLPX and EEX (with the restriction $0 \le x_i \le x_{\max}$ argumented by 2.5%)

Moreover, portfolios constructed for both electricity markets consist of contracts for all hours during the day as opposed to the portfolios built only for POLPX and EEX. From the point of view of retailers, this can be seen as a positive aspect of this approach. Nevertheless, the observed problem of negative portfolio return, caused by negative energy prices on EEX, needs further investigation and analyses.

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