Barbara Glensk
RWTH Aachen University
Alicja Ganczarek-Gamrot
Grażyna Trzpiot
Uniwersytet Ekonomiczny w Katowicach

VALIDATION OF MARKET RISK ON THE ELECTRIC ENERGY MARKET – AN IRC APPROACH

Introduction

After the world-wide credit crisis of the years 2007 and 2008 the Basel Committee proposed new capital charges to complement the existing market risk capital requirements [*Basel Committee on Banking Supervision*, 2009, 2011]. We present a framework for the *Incremental Risk Charge* (*IRC*) as the new capital requirement for market risks in abank's trading book ("Basel 2.5"). These are Value-at-Risk-type measures projecting losses over a one-year capital horizon at a 99.9% confidence level. We discuss selected risk market factor models to derive simulation-based loss distributions and the associated risk figures. Example calculations and implementation aspects complementing the discussion are based on electric energy markets. We introduce three different quantile risk measures *Value-at-Risk* (*VaR*), *Stress VaR* (*sVaR*) and *Incremental Risk Charge* (*IRC*) based on the tail of return distribution. The main goal of this paper is to validate the risk level on the electric energy market in Poland and Germany.

1. Measures of risk

When we take the financial decisions, at the same time we take the risk. The notion of risk is the property of the future. We have many sources of risk: the changes of prices, the uncertainty of keeping the conditions of a contract, the impossibility of closing a position on the financial market, the changes in law and the risk of a strategy [Jajuga, Jajuga, 1998; Tarczyński, 2003].

If we want to estimate the future risk, we must measure it. There are a lot of different measures of risk. We can divide them into three groups: measures of volatility, measures of sensitivity and measures of downside risk [Jajuga, Jajuga, 1998; Tarczyński, 1997]. In this paper we present quantile downside risk measures such as: *VaR*, *sVaR* and *IRC*.

The first group of risk measures comprises parametric measures, which are based on parameters of probability distribution. The most popular of them is the standard deviation of the rate of return, which at foundation of normal distribution is an efficient estimator of volatility:

$$s = \sqrt{\frac{1}{n-1}\sum_{t=1}^{n}(R_t - \bar{R})^2}\,, \tag{1}$$

where $\bar{R}$ is an average rate of return,

$R_t = \frac{P_t - P_{t-1}}{P_{t-1}}$ is a linear rate of return in timet,

or

$R_t = \ln(\frac{P_t}{P_{t-1}})$ is a logarithmic rate of return in time t,

P_t P_{t-1} are the prices.

Times series on energy market have a number of main characteristic such as: truncated distribution (Fig. 1), fat tails (Fig. 1-2), price spikes (Fig. 3), seasonality inboth prices and volatility mean revision, and a time to maturity effect (Fig. 4) – [Blanco, 1998].

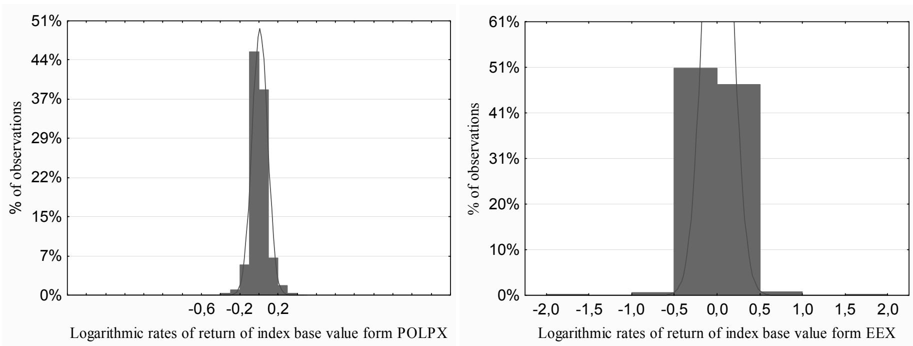

Fig. 1. Histograms of logarithmic rates of return of indexes base from 01.2009 to 28.09.2012 on POLPX and EEX

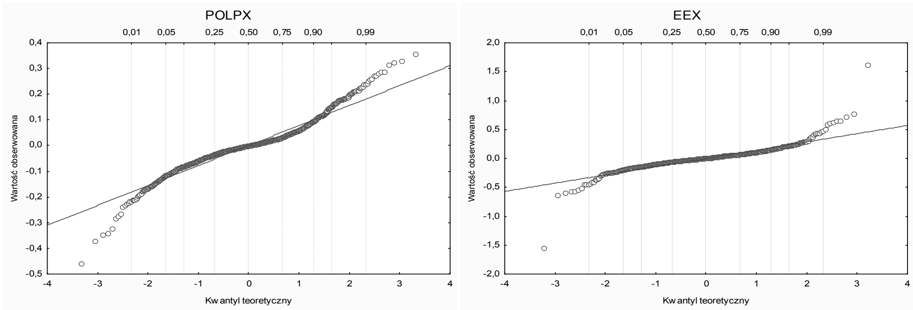

Fig. 2. QQ plot of logarithmic rates of return of indexes base from 01.2009 to 28.09.2012 on POLPX and EEX

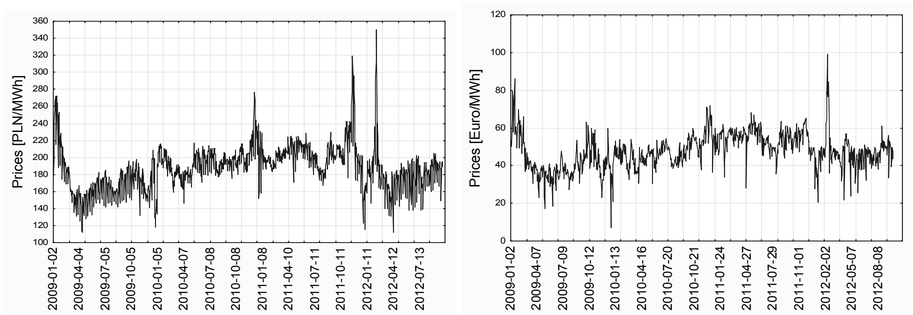

Fig. 3. Time series of values of indexes base from 01.2009 to 28.09.2012 on POLPX and EEX

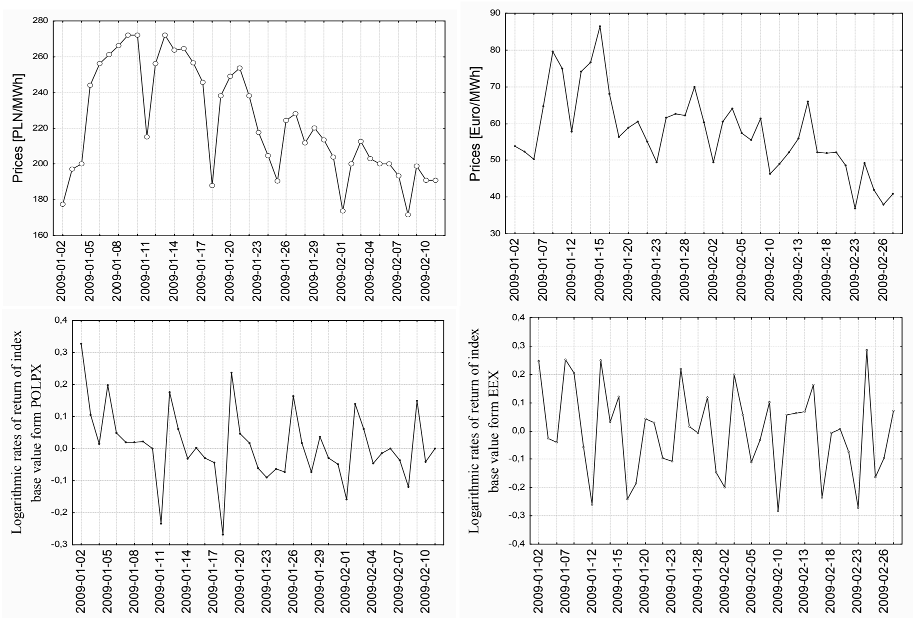

Fig. 4. Time series of values of indexes base and logarithmic rates of return of indexes base from 01-02.2009 on POLPX and EEX

In this case the downsides measure are more appropriate for risk estimation than classical standard deviation. Downside risk measures allow to measure unwilling deviations from an expected rate of return. One of them is *VaR*. *VaR* is such a loss in value, which cannot exceed the given probability $\alpha \in (0,1)$ [Jajuga, Jajuga, 1998; Weron, Weron, 2000; Alexander, Baptista, Yan, 2012]:

$$P(W \leq W_0 - VaR) = \alpha, \quad (2)$$

where:

W_0 is a present value,
W is arandom variable, value at the endof duration of investment.

Noticed by $Q_\alpha (W)$ α-quantile we can write [Trzpiot, Ganczarek, 2003; Colon, Cotter, 2012]:

$$Q_\alpha (W) = W_0 - VaR. \quad (3)$$

Noticed by $Q_\alpha (R)$ *as* α-quantile of a rate of return we can write:

$$Q_\alpha(R) = \frac{W_\alpha - W_0}{W_0} \quad \text{or} \quad Q_\alpha(R) = ln(\frac{W_\alpha}{W_0}) \quad (4)$$

We have now:

$$VaR = Q_\alpha (R) W_0 \text{ or} VaR = -(1\text{-}e^{Q\alpha(R)})W_0. \quad (5)$$

Another downside measures are *sVaR* and *IRC*. Let *U* mean the running value of energy and *R* is a rate of return, then we have [Trzpiot, Ganczarek, 2003; Wilkens, Brunac, Chorniy, 2011]:

***VaR*, *sVaR* and *IRC* for prices of electric energy:**

$$VaR_{95\%} = Q_{0,95}(R) * U \quad \text{or} \quad VaR_{95\%} = \quad (1 - e^{Q_{0,95}(R)}) * U \quad (6)$$

$$sVaR_{99\%} = Q_{0,99}(R) * U \quad \text{or} \quad sVaR_{99\%} = \quad ((- e^{Q_{0,99}(R)}) * U$$

(7) $IRC = VaR_{99,9\%} = Q_{0,999}(R) * U$ or

$IRC = VaR_{99,9\%} = \quad ((- e^{Q_{0,999}(R)}) * U$ (8)

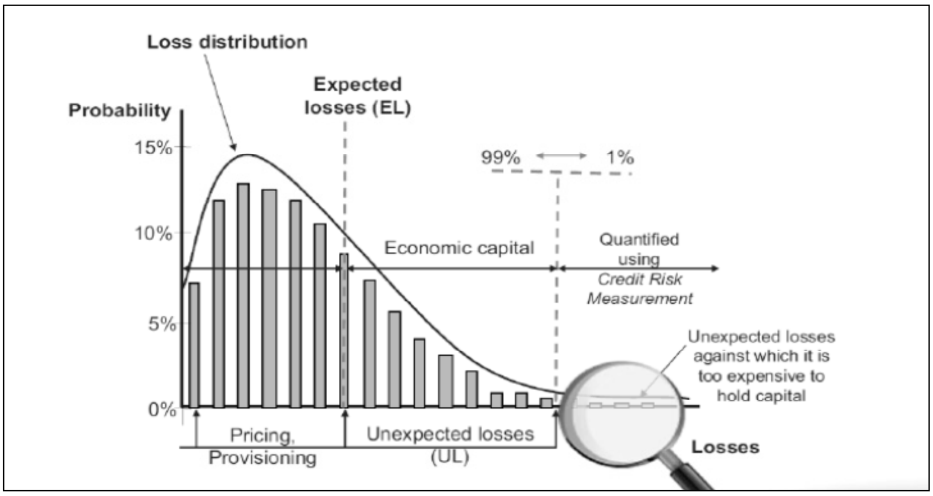

Fig 5. *sVaR*

Source: [WWW1].

IRC sets a high standard for seeking to model specific risk, the trading book capital charge comprises three essential components: the general market risk charge and the specific risk charge (using a one day or 10-day *VaR* at the 99% confidence level) plus the Incremental Risk Charge (IRC) that must be calibrated to and measured at a 99.9% confidence level over a capital horizon of one year.

According to the guidelines of the *European Banking Authority* [2011], at least for *IRC*, the loss quantiles should be derived relative to the mean: "[…] as risk computations are made on historical probability and not on risk-neutral probability, a portfolio may have a positive or a negative trend. […] For the sake of simplicity […] the *IRC* should be based on unexpected losses only" (p. 18).

2. Comparative risk analysis

The Polish Power Exchange (POLPX) was started 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 (CO_2 spot) and the Intraday Market. All these markets differ with respect to an investment horizon length and the traded commodity.

The result of the merger of the two German power exchanges in Leipzig and Frankfurt was the establishment in 2002 the European Energy Exchange AG (EEX) in Leipzig. 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 European Energy exchanges assuming an active role in the development and integration process of the European market.

We will work in a few steps. First, we can identify risk factors to be stressed. Next we will construct the stress scenarios and translate scenarios into model drivers. At the end we will analyze the outputs of stress analysis.

Based on logarithmic daily rates of return of indexes noted on POLPX and EEX spot markets from 01.2009 to 28.09.2012 we estimated *VaR* by equations (6, 7, 8). We made the estimation for four periods of the analyzed time:

- from 01-12.2009,
- from 01.2009 to 12.2010,
- from 01.2009 to 12.2011,
- from 01.2009 to 28.09.2012.

The results of risk measure estimation are presented in Tab. 1-8. We estimated *VaR* in two independent ways: by historical simulation (10 000) − (Tab. 1-2 and Tab. 5-6) and by historical percentiles (Tab. 3-4 and Tab. 7-8).

Table 1

α-quantiles of daily rates of return for the POLPX index – historical simulation 10000

Measures of risk	2009	2010	2011	2012
$Q_{95\%}$	0.1748	0.1415	0.1221	0.1479
$Q_{99\%}$	0.2364	0.2216	0.2116	0.2371
$Q_{99,9\%}$	0.3273	0.3273	0.3273	0.3273

Table 2

Risk measures[EURO/MWh] for the POLPX index – historical simulation 10 000[1]

Measures of risk	2009	2010	2011	2012
$VaR_{95\%}$	6.19	6.07	4.91	7.33
$sVaR_{99\%}$	8.65	9.91	8.90	12.31
$IRC = VaR_{99,9\%}$	12.55	15.46	14.62	17.81
Price of the index at the end of the year [EURO/MWh]	32.42	39.94	37.77	46.00

[1] Price of index at the end of the year [EURO/MWh] is a price of index base (IRDN) from POLPX noted at the end of the year 2009, 2010, 2011 and 28.09.2012 multipled by average conversion rates of EURO/PLN obtained from http://www.nbp.pl for the same date. The Value of Risk measure was calculated based on the same average conversion rates of EURO/PLN.

The results in Tab. 2 indicate that on the POLPX with probability 0.95 we couldn't lose more than 6.19 [EURO/MWh] at the end of 2009, 6.07 [EURO/MWh] at the end of 2010, 4.91[EURO/MWh] at the end of 2011 and 7.33 [EURO/MWh] on 28th September. Generally, we obtained the higher level of risk value for the higher value of confidence level [Pflug, 2000; Rockafellar, Uryasev, 2000; Trzpiot, Ganczarek, 2003]. The results in Tab. 4 are interpreted similarly to the results in Tab. 2. We can observe that the values of risk calculated by historical simulation are greater than the values of risk estimated by historical percentiles.

Table 3

α-quantiles of daily rates of return for the POLPX index – historical percentiles

Measures of risk	2009	2010	2011	2012
$Q_{95\%}$	0.1725	0.1425	0.1227	0.1479
$Q_{99\%}$	0.2313	0.2125	0.2117	0.2366
$Q_{99,9\%}$	0.3062	0.2851	0.2846	0.3248

Table 4

Risk measures{EURO/MWh] for the POLPX index – historical percentiles

Measures of risk	2009	2010	2011	2012
$VaR_{95\%}$	6.10	6.12	4.93	7.33
$sVaR_{99\%}$	8.44	9.45	8.90	12.28
$IRC = VaR_{99,9\%}$	11.62	13.18	12.43	17.65
Price of index at theend of the year [EURO/MWh]	32.42	39.94	37.77	46.00

The results in Tab. 6 indicate that on the EEX with probability 0.95 we could not lose more than 7.83 [EURO/MWh] at the end of 2009, 11.69 [EURO/MWh] at the end of 2010, 8.86 [EURO/MWh] at the end of 2011 and 10.29 [EURO/MWh] on 28thSeptember. The results in Tab. 8 are interpreted similarly to the results in Tab. 6. As on POLPX, on EEX we can observe that values of risk calculated by historical simulation are greater than the values of risk estimated by historical percentiles. Moreover, the level of risk on EEX is much higher than the level of risk on POLPX. Especially, the risk estimated by IRC, which represents possible losses of very low probability (0.001).

Table 5

α-quantiles of daily rates of return for the EEX index – historical simulations 10 000

Measures of risk	2009	2010	2011	2012
$Q_{95\%}$	0.2524	0.2280	0.2047	0.2129
$Q_{99\%}$	0.6015	0.4547	0.4358	0.4937
$Q_{99,9\%}$	1.6083	1.6083	0.7666	1.6083

Table 6

Risk measures{EURO/MWh] for the EEX index – historical simulations 10 000[2]

Measures of risk	2009	2010	2011	2012
$VaR_{95\%}$	7.83	11.69	8.86	10.29
$sVaR_{99\%}$	22.49	26.26	21.31	27.68
$IRC = VaR_{99,9\%}$	108.89	182.23	44.96	173.20
Price of index at the end of the year [EURO/MWh	27.26	45.62	39.01	43.36

Table7

α-quantiles of daily rates of return for the EEX index – historical percentiles

Measure of risk	2009	2010	2011	2012
$Q_{95\%}$	0.2498	0.2264	0.2047	0.2108
$Q_{99\%}$	0.5149	0.4509	0.4337	0.4592
$Q_{99,9\%}$	1.3903	1.1706	0.9518	0.7876

Table 8

Risk measure{EURO/MWh] for the EEX index – historical percentiles

Measure of risk	2009	2010	2011	2012
$VaR_{95\%}$	7.74	11.59	8.86	10.17
$sVaR_{99\%}$	18.36	25.99	21.18	25.27
$IRC = VaR_{99,9\%}$	82.22	101.46	62.04	51.95
Price of index at the end of the year [EURO/MWh	27.26	45.62	39.01	43.36

3. Stress test

We used a failure test to estimate the effectiveness of *VaR* by Kupiec [1995], [Blanco, Oks, 2004]. We test the hypothesis:

H0 : $\omega = 1 - \alpha$
H1 : $\omega \neq 1 - \alpha$

where ω is a proportion of the number of the research results exceeding VaR_α to the number of all results. The number of the excesses of VaR_α has binomial distribution with a given size of the sample.

The test statistic is:

$$LR_{uc} = -2\ln[\alpha^{T-N}(1-\alpha)^N] + 2\ln\left\{\left[1-\left(\frac{N}{T}\right)^{T-N}\right]\left(\frac{N}{T}\right)^N\right\}, \quad (9)$$

[2] Price of index at the end of the year [EURO/MWh] is a price of the index base from EEX noted at the end of the year 2009, 2010, 2011 and on 28.09.2012.

where:
N – is the number of the crossing of VaR_α,
T – is the length of a time series,
$1-\alpha$ – is a given probability with which VaR_α cannot exceed the loss of value.

The statistics LR_{uc} has χ^2 asymptotic distribution with 1 degree of freedom.

In Tab. 9-12 we present the results of the Kupiec test for risk measures calculated in the previous section. Generally, for every presented method of *VaR* estimation on two indexes from POLPX and EEX, we cannot reject the null hypothesis with the significant level of 0.05 only for *IRC*. The number of excess *VaR* for $VaR_{0,95}$ and *sVaR* is higher than excepted. As a consequence, based on this result we can say, that only *IRC* is an appropriate measure to estimate the level of risk on electric energy spot markets.

Table 9

P-value of Kupiec test for risk measure on POLPX − historical simulation 10 000

Measure \ Year	2009	2010	2011	2012
VaR	0.0000	0.0000	0.0000	0.0000
stress *VaR*	0.0135	0.0005	0.0072	0.0000
IRC	1.0000	1.0000	1.0000	0.1466

Table 10

P-value of Kupiec test for risk measure on POLPX – historical percentiles

Measure \ Year	2009	2010	2011	2012
VaR	0.0000	0.0000	0.0000	0.0000
stress *VaR*	0.0047	0.0001	0.0072	0.0000
IRC	0.0974	0.1484	0.0765	0.0391

Table 11

P-value of Kupiec test for risk measure on EEX – historical simulations 10 000

Measure \ Year	2009	2010	2011	2012
VaR	0.0000	0.0000	0.0000	0.0000
stress *VaR*	0.0141	0.0005	0.0004	0.0001
IRC	1.0000	1.0000	0.3143	1.0000

Table 12

P-value of Kupiec test for risk measure on EEX – historical percentiles

Measure \ Year	2009	2010	2011	2012
VaR	0.0000	0.0000	0.0000	0.0000
stress *VaR*	0.0034	0.0001	0.0001	0.0000
IRC	0.0731	0.1257	0.3143	0.1574

Discussion

The Basel Committee/IOSCO Agreement reached in July 2005 contained several improvements in the capital regime for trading book positions. Among these revisions there was a new requirement for banks that models specific risk to measure and hold capital against default risk that is incremental to any default risk captured in the bank's *Value-at-risk* (*VaR*) model. The incremental default risk charge was incorporated into the trading book capital regime in response to the increasing amount of exposure in banks' trading books to credit-risk related and often illiquid products whose risk is not reflected in *VaR*.

The decision was taken in light of the recent credit market turmoil where a number of major banking organizations experienced large losses, most of which were sustained in banks' trading books. Most of those losses were not captured in the 99%/10-day *VaR*. Since the losses did not arise from actual defaults but rather from credit migrations combined with widening of credit spreads and the loss of liquidity, applying an incremental risk charge covering default risk only would not appear adequate.

The Committee expects financial institutions to develop their own models for calculating the *IRC* for trading book positions.

1. Banks using internal models in the trading book must calculate astressed value-at-risk based on historical data from a continuous 12-month period of significant financial stress.
2. Banks using internal specific risk models in the trading book must calculate an incremental risk capital charge (*IRC*) for credit sensitive positions which captures default and migration risk at alonger liquidity horizon.
3. Securitization positions held in the trading book will be subject to the Basel II securitization charges, similar to securitization positions held in the banking book.
4. So-called correlation trading books are exempted from the full treatment for securitization positions, qualifying either for arevised standardized charge or a capital charge based on acomprehensive risk measure.

Accordingly, we plan the next paper to deal with contracts on energy market.

Conclusion

Based on *VaR*, *sVaR* and *IRC* estimated on POLPX and EEX for base indexes from 01.2009 to 28.09.2012, we can say that the level of risk on the EEX spot market is higher than the level of risk on the POLPX spot market. The difference is very significant for extreme risk. We can say that similarly to the financial market, *IRC* is also much better for risk estimation than *VaR* or *sVaR* on the spot electric energy market.

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Summary

The aim of this paper is to describe and measure risk on the Polish & German Energy Market. The risk was estimated with three types of Value-at-Risk measures: VaR, stress VaR and Incremental Risk Charge (IRC). These measures were calculated on time series of logarithmic daily rates of return of indexes from the Polish Power Exchange (POLPX) andthe European Energy Exchange (EEX) spot market. Based on time series from 01.2009 to 28.09.2012 we attempted to answer the two questions: which measure is more appropriate for risk estimation, and where the risk level is higher.