

CREDIT VALUE ADJUSTMENT AND ECONOMIC
MOTIVATION TO TRADE ON PXE

DOI:10.18267/j.pep.517

Igor Paholok*

Abstract:

Electricity forward contracts can normally be traded in two ways in the Czech Republic: OTC forwards, which means bilaterally or bilaterally through a broker, and futures through the Power Exchange Central Europe. Each way has its own economic pros and cons. As the most crucial point, a counterparty risk and costs of funding are usually mentioned. Contracts traded on the power exchange bear less or no credit risk, as every deal is paired *via* central counterparty. On the other hand, the power exchange requires a margin deposit and daily profit and loss settlement which might increase funding costs. The fact that the counterparty risk is lower for exchange contracts with higher funding costs is well-known, but rarely quantified. We use the so-called Credit Value Adjustment concept in order to quantify the market value of the credit risk. We compare this value with potential funding costs. The aim of this paper is to compare both the OTC and exchange ways of trading using risk-adjusted economic characteristics.

Keywords: Credit Value Adjustment, counterparty risk, power futures, futures margining, Merton model, Wiener process

JEL Classification: C53, G17, Q47, Q49

1. Introduction

The recent financial crisis reveals shortcomings of common risk management standards. For the purpose of this paper, we have chosen to focus on the concept called Credit Value Adjustment (CVA). CVA is the difference between the risk-free portfolio value and true portfolio value that takes into account the possibility of counterparty's default. In other words, CVA is the market value of counterparty credit risk.

Having such a powerful tool as CVA, we can quantify the market value of credit/counterparty risk. With knowledge about initial margin parameters on futures exchange, level of interest rates and futures prices volatilities, we can quantify the expected value of funding costs generated by the need of keeping cash blocked as an initial margin and cash readiness to cover daily settlement of variation margin. Finally, we can compare the CVA with the costs of funding and decide whether it is more beneficial to trade *via* a power

* Igor Paholok, University of Economics, Faculty of Finance and Accounting, Prague (paholok@institute.cz).

The research has been supported by the Czech Science Foundation Grant No. 402/09/0732 "Market Risk and Financial Derivatives". This paper was supported by Grant IG102030, Project title: "Chování investičních instrumentů v kontextu finančních krizí", Project No. 8/2010.

exchange or OTC. We presume that trading *via* power exchange bears no credit risk, but evokes costs of funding. On the other hand, OTC trading normally bears non-zero credit risk but is less expensive from a funding point of view, with other conditions (fees, market liquidity, non-economic and administrative consequences) *ceteris paribus*.

As we do not have sufficient historical data about energy companies' probabilities of default over time and their reactions to the movement of power contracts price, we can work only with model based data. To do so, we use a modified Merton model (see for example Yi, Tchernitser, Hurd, 2009) with a predefined matrix with initial values of the solvency ratios (asset over debt) and the ratios' volatilities. Data about historical prices' volatilities are captured directly from the Power Exchange Central Europe for Czech market and data about related interest rates are market based as well.

The next section introduces the models applied, and in Section Three we present the models' applications. The conclusion of the results is summarized in the Section Four.

2. Model Definition

In this section, we define the mathematical fundamentals of the modified Merton model, Credit Value Adjustment, and we define the funding costs and finally we present the way of economic comparison of OTC and exchange type of trading.

2.1 Counterparty risk and credit value adjustment

Counterparty credit risk is the risk that the counterparty to a financial or commodity contract will default prior to the expiration of the contract and will not make all the payments required by the contract. There are two features that set counterparty risk apart from more traditional forms of credit risk: the uncertainty of exposure and bilateral nature of credit risk (Pykhtin and Zhu, 2007). Whenever a counterparty in a derivative contract defaults, the subject loses the positive present value of this contract. This type of loss is usually called the contract's replacement costs. If the present value is zero or negative, the subject's loss is zero. If the value of contract i at time t is $V_i(t)$, the contract level exposure $E_i(t)$ is:

$$E_i(t) = \max\{V_i(t), 0\} \quad (2.1)$$

Only current exposure is known with certainty, while future exposure is uncertain. We apply a path-dependent simulation in order to generate possible market scenarios and, consequently, the possible future value of the contract level exposure. The stochastic differential equation is usually used and the generalized geometric Brownian motion (GBM) is frequently used for modelling FX rates and stock indices:

$$dX(t) = \mu X(t) dt + \sigma X(t) dW_t \quad (2.2)$$

Where $X(t)$ is the value of a market factor which is supposed to be simulated, μ is drift and σ is deterministic volatility. W_t is a Wiener process. The analytical solution of the stochastic differential equation is

$$X(t + \delta t) = X(t) \exp \left[\left(\mu - \frac{1}{2} \sigma^2 \right) \delta t + \sigma W \delta t \right] \quad (2.3)$$

To keep it simple, we also use GBM for electricity future prices modelling, however, the appropriateness of this application could be discussed. The usage of a more suitable model is analysed in the Section Three of this paper (the jump diffusion mean reverting

model is more suitable for an electricity spot price series and the two factors model for an electricity forward/futures price series).

After the simulation (k simulated paths) of market factors is completed we can evaluate the exposure. The conditional valuation is given by

$$V_i(t, \{X(t)\}_{j=1}^k) = E \left[V_{MTM}(t, \{X(t)\}_{j=1}^k) \middle| \{X(t) = x_j\}_{j=1}^k \right] \quad (2.4)$$

Having conditional contract value, we can quantify potential discounted loss L^* by

$$L^* = 1_{\{\tau \leq T\}} (1 - R) \frac{B_0}{B_t} E(\tau) \quad (2.5)$$

Denoting the time of counterparty default by τ , B_t is the future value of one unit of the base currency invested today at the prevailing interest rate for t r_t . R denotes recovery rate, a constant fraction of exposure which will be paid by the counterparty in case of default. T is the maturity of the contract (or the time until we intend to keep position) and $1_{\{\cdot\}}$ is the indicator function that takes the value of one if the argument is true (and zero otherwise). n represents the number of years.

The Credit Value Adjustment is consequently given by the risk-neutral expectation of the discounted loss. The risk-neutral expectation of Equation 2.5 can be written as

$$CVA = E^Q[L^*] = (1 - R) \int_0^T E^Q \left[\frac{B_0}{B_t} E(\tau) \middle| \tau = t \right] dPD(0, T) \quad (2.6)$$

Where $PD(0, t)$ is the risk-neutral probability of counterparty default between times 0 and T .

In reality, we have to calculate with the counterparty level exposure (instead of contract level exposure) including all netting and collateral agreements. However, for the purposes of this paper, we work on a contract level without a collateral.

2.2 Modified Merton model

As mentioned above, we have insufficient data about companies' default probabilities and their possible reaction to the movement of electricity contracts prices. Hence, we apply the so-called structural model of credit risk, the modified version of the Merton model. The solvency ratio (asset over debt) Y_t has an initial value of Y_0 , which can be observed directly from companies' balance sheet. Based on the model, we assume that the solvency ratio Y_t is specified to be a Geometric Brownian motion (GMB). When the solvency ratio is lower than one (or log of the solvency ratio lower than 0), a company is technically in default, because the value of assets is lower than the value of debts. We suppose that an underlying contract matures at a future time T , therefore the default situation is defined as a state, when Y_T is lower than one. Paths of Y_t development are simulated using GMB, with simplification, that we do not consider a drift parameter:

$$Y_t = Y_0 + \sigma_Y W_t \quad (2.7)$$

Where W_t is the Wiener process and σ_Y is volatility of the solvency ratio. The initial value of the solvency ratio Y_0 , can be observed from a company's balance sheet. However, we are limited by the fact that the balance sheet shows a company's state at a specific time, rather than the state over time. The volatility of the solvency ratio σ_Y cannot be directly

observed, but could be estimated by a particular rating model. σ_y depends on a company's strategy, level of risk management and portfolio diversification, the volatility of electricity contract prices *etc.*

The solvency ratio is usually defined as the assets over debt ratio (or log of the assets over debt ratio). Using this definition, we define the default as a state when Y_t is lower than one (zero in case of logarithm).

The default probability for time T , $PD(T)$ can be calculated by conditioning

$$PD(T) := E[P(Y_T < 1 | Y_0)] \quad (2.8)$$

In Equation 2.6 we calculate with $PD(0, T)$, but we get $PD(T)$ using the modified Merton model. For the purpose of this paper, we assume that the difference between both PD s is very close to zero (we work with the time horizon within one year) and therefore we can substitute $PD(0, T)$ with $PD(T)$.

2.3 Funding costs

As was already mentioned, trading *via* an exchange is usually connected to additional funding costs. The first type of such costs is given by the obligation to deposit the required margin. The amount of the required margin is set by the margin coefficient M_{ex} which is set by an exchange (we do not consider the right of clearing participant to set the higher margin requirements) for each type of the traded contracts. Whenever a trading participant opens a position he is obliged to deposit the margin. This deposited margin yields an interest, which is usually lower than the market interest rate for an overnight period. Normally we intend to keep position for a longer time (until time T) than the overnight period is. The difference between the market rate for period $(0, T)$ and the exchange yield for deposited margins is expressed as $(r_{(0,T)} - r^{ex})^{T/n}$ where $r_{(0,T)}$ represents interest rate for particular period, r^{ex} represents yield paid by an exchange or clearinghouse and n represents the number of years. The cost of the margin deposit is given by the following equation:

$$CM = M_{ex} N (r_{(0,T)} - r^{ex})^{T/n} \quad (2.9)$$

where N denotes the number of contracts (or MWh) in an opened position. We can assume to have one contract, and N equals one.

Another type of funding cost is conditional. Whenever the value of the contract is lower than the value of the given contract one day before, the trading participant must settle this mark-to-market loss. This is not required when the contract is traded OTC. The funding cost of the potential daily loss settlement is therefore given as the sum of the potential daily losses multiplied by the actual market overnight interest rate r_t^{ON} .

$$C_{Mm} = \sum_{t=0}^T E \left[(V_0 - V_i(t)) N \frac{r_t^{ON}}{360} \middle| \{X(t) = x_j\}_{j=1}^k \right] \quad (2.10)$$

The total amount of funding costs is given by the sum of the cost of margin deposit and the cost of potential daily loss settlement discounted to the present value by r_t :

$$C = \left(M_{ex} N (r_{(0,T)} - r^{ex})^{T/n} + \sum_{t=0}^T E \left[(V_0 - V_i(t)) N \frac{r_t^{ON}}{360} \middle| \{X(t) = x_j\}_{j=1}^k \right] \right) \left(\frac{1}{(1 + r_t)^T} \right) \quad (2.11)$$

2.4 Economic motivation to trade *via* power exchange

As we are able to quantify the potential costs of counterparty risk and the value of the potential funding costs, we can compare both values. While the potential costs of credit risk are typical for OTC trading and minimal for exchange trading (and *vice versa*, the potential funding costs are more characteristic for an exchange) we can assess the economic motivation to trade in each way. We assume that the other parameters which can influence the traders' motivations are not relevant (e.g. fees, liquidity, administrative obligations are the same or very similar). The situation when we are indifferent to each way of trading could be defined as an equality between the potential costs of credit risk and the potential funding costs:

$$\begin{aligned} (1-R) \int_0^T E^Q \left[\frac{B_0}{B_t} E(t) | \tau = t \right] dPD(0, t) = \\ = \left(M_{ex} N(r_{(0,T)} - r^{ex})^{T/n} + \sum_{i=0}^T E \left[(V_0 - V_i(t)) N \frac{r_i^{ON}}{360} \left| \{X(t) = x_j\}_{j=1}^k \right. \right] \right) \left(\frac{1}{(1+r_\tau)^\tau} \right) \quad (2.12) \end{aligned}$$

We define the *PD* for which the equation is valid as the *Critical PD*.

Whenever the potential costs of counterparty risk exceed the potential costs of funding trading *via* exchange is more economically effective and *vice versa*.

Having Equation 2.12, we can examine the optimal way of trading for different *PD*, *R* and underlying asset price ($X(t)$) volatility. Other parameters are supposed to be exogenous – set by exchange or in the case of interest rates by the money market.

The following section reveals the application of the previously described analysis on the Czech forwards/futures power market.

3. Application to the Czech Power Market

In this section, we describe the data we use, the futures market data from the Power Exchange Central Europe and the related interest rate data for the euro. All data we use contain historical end of day observations from July 17, 2007 until December 31, 2010. The data source was the PXE Front End Terminal NG for power futures time series and Reuters Xtra Terminal for interest rates data.

3.1 Czech power futures data characteristic

Trading with electricity futures contracts had started on July 17, 2007 on the PXE. The list of traded contracts was continuously extending. The portfolio of traded products now includes power futures with base load and peak load day time mode of delivery, month futures with delivery starting from the following month to the next five months, quarters futures with delivery starting from the following quarter to the next four quarters and years futures for the following three years. There is physical and financial settlement for all types of traded futures contracts for the electricity with the delivery location within

the electricity system in the Czech Republic¹. More than 190 different contracts have been traded since the PXE founding.

For the purpose of this essay, we need to examine the development of prices more closely. From the daily observed closing price we can calculate log returns, which we can use for the calculation of contracts' historical² price volatility σ . As a quite large amount of contracts has been traded since July 17, 2007, we have to aggregate contracts according their characteristics into six groups; base load and peak load months, quarters and years. Extended characteristics of contracts' volatilities are presented in Appendix 1. Aggregated characteristics, which we use for CVA calculation, are listed in Table 1.

Table 1 | Characteristics of Historical Volatilities for Particular Contract Groups

Contract type / Parameter	1-percentile (%)	Average (%)	99-percentile (%)	Margin (EUR)
BL M	0.01	0.81	1.87	4.5
BL Q	0.01	0.8	2.08	2.9
BL Y	0.01	0.71	1.36	2.7
PL M	0.01	0.83	2.05	7.5
PL Q	0.01	0.81	2.47	3.7
PL Y	0.01	0.82	1.55	3.5

Source: PXE data, author's analysis

Subsequently we can use the obtained historical volatilities as a parameter for Equation 2.3 to simulate the paths of the Brownian motion and to evaluate the portfolio according 2.4. The usage of the Wiener process assumes the normality of daily returns. However, this assumption is arguable, we work with 190 time series with different characteristics of returns distribution and therefore, the usage of a proxy distribution is inescapable. The illustration of the different returns distribution of PXE's contracts is illustrated on Figure 1.

In energy companies' practice, a more sophisticated model than the Wiener process could be used in the process of contract's volatility modelling. The Two-Factors Model (see for example Ruediger, Schindlmayr, Reik (2005)), which incorporates the fact that the volatility of the contract increase with decreasing time to delivery, could be a suitable one. Unfortunately, we cannot apply such model in our case, as the contracts' characteristics have changed dramatically over time since 2007.

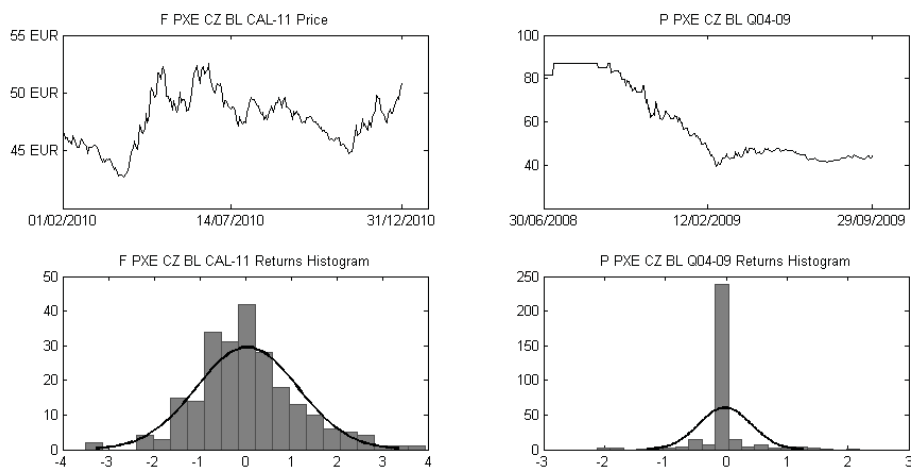
At the end of this subsection, it has to be mentioned, that in the true sense of the word the market data from PXE are not necessarily from the market. Whenever the liquidity is

1 In the PXE, contracts with the delivery location within the electricity system in the Slovakia and Hungary are also traded. We are concerned with Czech power futures in this paper, however, similar methodology could be applied also to other countries.

2 Options for Czech power futures are not traded on the PXE. Therefore we cannot use implied volatilities.

low, and no contract is traded during the day, the exchange officer might adjust the end of day prices according particular exchange rules.

Figure 1 | The Illustration of Different Returns Distribution of PXE's Contracts



Source: PXE data, author's analysis

3.2 Euro interest rates data characteristic

According to Equation 2.11 the funding costs depend on several interest rates of a particular currency which is the euro. Compared to OTC trades, the margin set by an exchange bears only the spot (overnight) rate minus the specific adjustment. The difference between the longer term yield $r_{(0,T)}$ and the yield which bears margin deposit on an exchange r^{ex} is assumed to be the opportunity costs of the obligation to keep the margin deposit. However, if we trade rather OTC, we do not have to deposit a margin, and therefore, the particular amount could be invested. The duration of our alternative investment T equals the length of the period we intend to keep the position in the particular power futures contract.

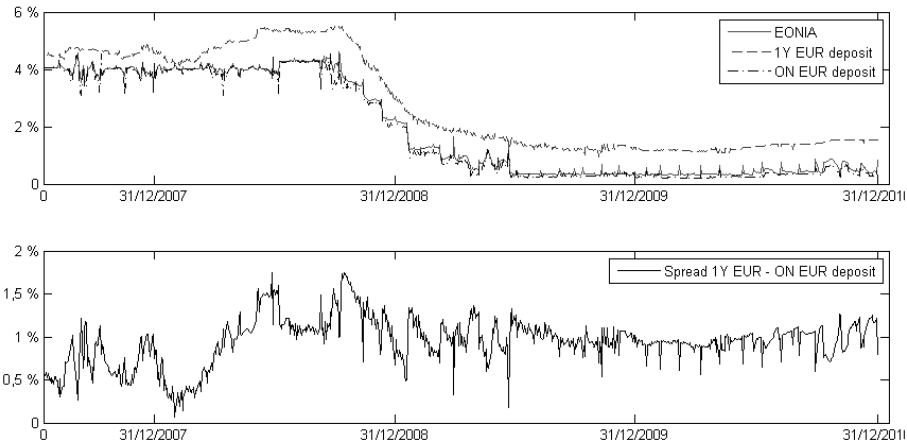
The second part of the defined funding costs is conditional. Whenever the end of day valuation, $V_i(t)$, of contracts we hold in a position on an exchange, decreases under the value at the time of contracts initiating V_0 , we have to settle that negative mark-to-market loss and *vice versa*. Anytime we open a position on an exchange, we have to take into account the potential funding costs which arise from the obligation of the daily profit/loss settlement. This daily settlement is not common on OTC markets, and if our mark-to-market position is negative, we do not have to settle it daily. The particular amount might therefore be invested in the overnight money market with the interest r^{ON} .

Deposited margins on PXE bears an interest, which is calculated as the EONIA³ minus 0.08 %. We suppose that we intend to keep position in the particular power future contract for a one year, therefore, we compare the PXE interest yield with the one-year deposit rate for the euro. The development of EONIA, the one-year euro deposit interest

³ Effective Overnight Index Average

rate, the euro overnight interest rate, and the difference between one-year euro rate and the rate paid by PXE for deposited margins since July 17, 2007 is presented in Figure 2.

Figure 2 | Development of Related Euro Interest Rates



Source: Reuters

After an overview of related interest rate development, it raises the question, which values of particular interest rates are supposed to be used in CVA and Critical PD calculation. If we calculate CVA in a real business situation, we should apply an appropriate interest rate model, for example the Vasicek model, Cox-Ingersoll-Ross model or Hull-White model, presented for example in Malek (2005). Historical data are used for model calibration, and current values are used as initial values in the selected interest rate model. For a historical study as presented in this paper we use an average of historical observation and the critical values calculated as 1st and 99th percentile, presented in Table 2. This can be considered as historical simulation.

Table 2 | Characteristics of Historical Related Euro Interest Rates

Parameter	1-percentile (%)	Average (%)	99-percentile (%)
r^{ON}	0.2	1.88	4.3
$r_{(0,T)} - r^{ex}$	0.27	0.95	1.62
$r_{(0,T)}$	1.11	2.84	5.47

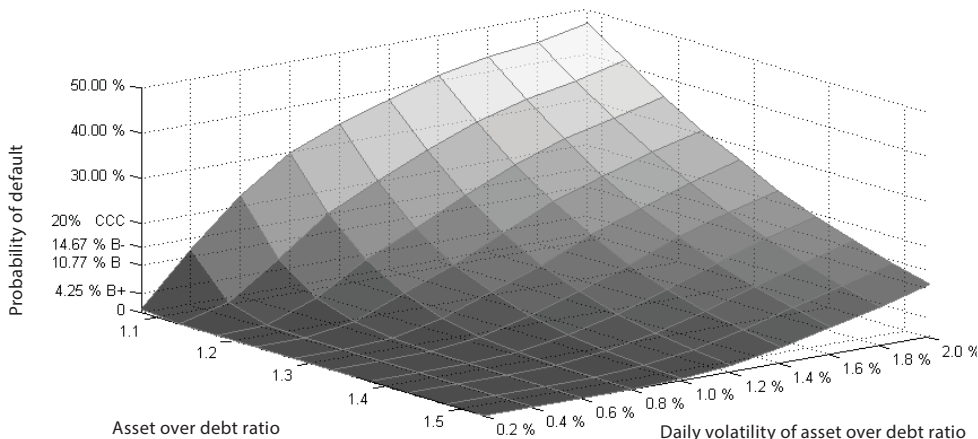
Source: PXE data, author's analysis

The results are also more objective than the results we would obtain if we used only values from the end of 2010.

3.3 Modified Merton model and default probabilities calculation

We do not have historical observation about energy companies' default probabilities. Instead of historical observation, we use the modified Merton model, as it was described in Section 2.2. Using a predefined range of assets over debt ratio $Y_0=(1.08; 1.53)$ and a predefined range of assets over debt ratio volatility $\sigma_Y=(0.002; 0.02)$ we obtain a range of realistic *PD*. Detailed *PD* distribution is presented in Appendix 2, graphically in Figure 3.

Figure 3 | Default Probabilities Obtained from the Modified Merton Model



Source: Author's analysis

3.4 The CVA and critical PD calculation

The data described in the previous sections are just input parameters for the CVA and Critical PD calculation.

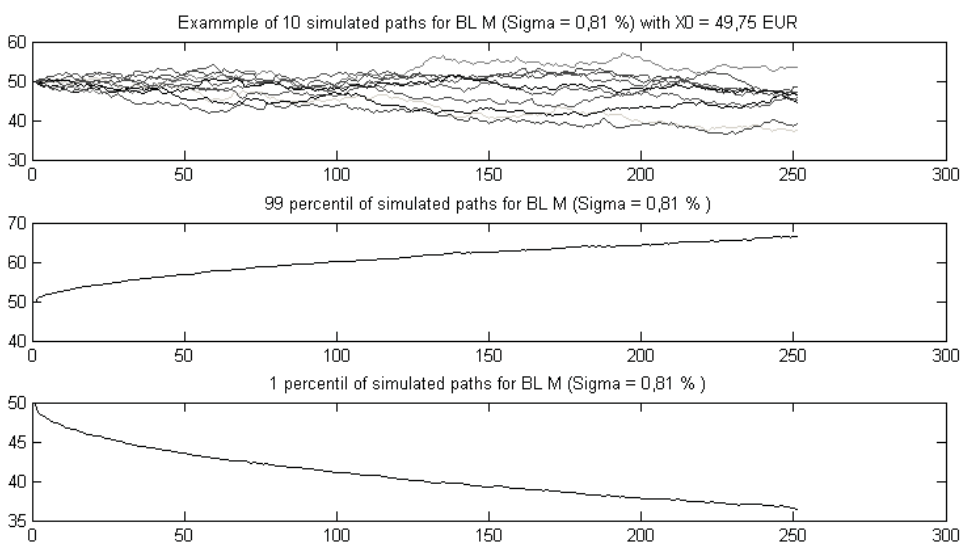
The historical price volatilities presented in Table 1 are inputs for the portfolio conditional value calculation. We assume that the portfolio is always composed of one single contract. CVA is calculated for one MWh of this contract. The PDs are obtained from the Modified Merton model and the recovery rate is set at 40%, which represents a market benchmark. The estimation of the recovery rate should be used in the firms' practice for each single counterparty. The average closing prices from December 31, 2010 was set as the starting point X_0 for each simulated time series, for each selected contract type. The period for which we intend to keep the position is set as 250 working days. We do not consider either of the products cascading⁴, nor the delivery period.

4 On the accounting day following the last trading day for a particular year futures series, each open position is replaced with an equivalent three month futures series (for January, February and March) and three corresponding quarter futures series (quarter for the second, third and fourth quarters). Each open position in the particular quarter futures series is replaced by an equivalent three month futures series.

The illustrative simulation for BL M time series with the average daily volatility $\sigma = 0.81\%$; and the initial value EUR 49.75, is depicted in Figure 4. The portfolio conditional value is set as the 99th percentile of all 10,000 simulated paths. We use the maximum of the conditional value series as an input for the CVA calculation.

The maximum of the presented conditional portfolio value series is 66.51. Our potential exposure equals the positive mark-to-market value of our portfolio. This is given by the difference between the initial value of the contract and the conditional value of the contract, which is EUR 16.75 for our example. This value is discounted with the deposit rate for a particular tenure (the average of a one-year deposit rate is in our case 2.84%), multiplied by $(1-RR)$, and finally, multiplied by PDs . The PDs are presented in Appendix 2 and the relevant CVAs in Appendix 3. CVA, as it was mentioned before, is the market value of credit risk which bears the counterparties in OTC trading.

Figure 4 | The Illustrative Simulation for the BL M Time Series



Source: Author's analysis

The funding costs contain two parts. The first one, cost of deposited margin, is calculated as the opportunity cost of the obligated margin deposit. We calculate with a margin requirement of EUR 4.5 in our illustrative case for the BL M contract type. According to Equation 2.8 we also calculate with the yield difference -0.95% . For the calculation of the second funding cost, we use the conditional value set as the 1st percentile of our stochastic simulation. The difference between the initial value of 1 MWh of electricity and the conditional V_t value is multiplied by the related spot interest rate. As we use the average value in this case, we calculate with the value $r^{ON} = 1.88\%$. The sum of both parts of the funding cost is finally discounted with the particular rate r_{tau} to receive the present value of the money. Funding costs are EUR 0.16 in our illustrative example. As it was mentioned before, the funding costs are the opportunity costs of electricity contracts traded *via* a power exchange.

The Critical PD, in other words, the probability of default for which it is economically irrelevant whether we trade *via* exchange or OTC is calculated as the PD for which CVA equals the funding costs. In our case, we got the critical PD 1.6% which represents a company with a credit rating somewhere between Ba2 and Ba3 of Moody's rating scale. If a counterparty has a rating or PD which is better than the critical value, we should trade OTC. If the counterparty's rating is worse than the critical, we should trade on an exchange.

After the illustrative calculation, we reveal the results of the critical PDs value for all product types presented in Table 1. We calculate the characteristic for the average values of daily volatilities as well as for 99th percentile and 1st percentile. We use the average values of the related interest rates from Table 2, for the funding costs calculations. Results of the described analysis is in the Table 3.

Table 3 | Values of the Critical PD for the Table 1 Contract Type Characteristics Data and Average of the Related Interest Rate Data from Table 2

Critical PD	Starting price (EUR)	1st percentile (%)	Average (%)	99th percentile (%)	Margin (EUR)
BL M	49.75	39.59	1.60	1.05	4.5
BL Q	50.44	27.13	1.49	0.97	2.9
BL Y	52.35	24.22	1.53	1.13	2.7
PL M	61.95	56.00	1.78	1.08	7.5
PL Q	63.1	27.04	1.44	0.82	3.7
PL Y	66.25	24.90	1.45	1.14	3.5

Source: PXE data, author's analysis

The critical PDs are very high for contracts with very low volatilities (around 1st percentile of all contracts traded on PXE). Therefore it is more economical to trade such contracts OTC. The critical PDs for the contracts with the average volatilities of each contract type, varies from 1.44% to 1.78%. We get the highest values for the month products, where the margin requirements are quite high. The critical PDs for high volatility contracts varies from 0.82% to 1.14%, which could be presented as the rating between Ba1 and Ba2 on the Moody's rating scale.

The average values of the related interest rates are quite high compared to the interest rates of a post-crisis period. Therefore, we perform an analysis where we use the average values of the contracts type volatilities of each contract type. But with the 1st percentile and 99th percentile of the related interest rate values as they are presented in Table 2. The results are in Table 4.

Table 4 | Values of the Critical PD for the Table 2 Related Interest Rate Data and Average of the Contract Type Characteristics Data from Table 1

Critical PD	Starting price (EUR)	1st percentile (%)	Average (%)	99th percentile (%)	Margin (EUR)
BL M	49.75	0.25	1.60	3.63	4.5
BL Q	50.44	0.20	1.49	3.32	2.9
BL Y	52.35	0.21	1.53	3.50	2.7
PL M	61.95	0.29	1.78	3.86	7.5
PL Q	63.1	0.21	1.44	3.33	3.7
PL Y	66.25	0.20	1.45	3.25	3.5

Source: PXE data, author's analysis

It is obvious that the critical PDs decrease dramatically when we use the low interest rate characteristics. For the period of very low interest rates the critical PDs implies Moody's rating around Baa2. Trading on the PXE is much more economical during the period with low interest rates than during the period with a high level of related interest rates.

4. Conclusion

The Credit Value Adjustment is a powerful tool, which allows us to quantify the market value of credit/counterparty risk. Using this tool we can perform the analysis of the economic effectiveness of both types of trading; OTC and *via* exchange. The funding costs, which are typical for exchange trading, can be compared to the CVA, which is the potential cost of OTC trading. The optimal way of trading can be recommended for the various parameters as the counterparty's default probability, the level of related interest rates, the volatility of traded instruments *etc.* Research shows how the critical probability of counterparty's default (the default probability for which it is economically indifferent whether we trade OTC or *via* exchange) varies with the different input parameters from the values around 50%, for the contracts with the very low volatility, to the values around 0.2% which represents credit rating around Baa2, for the very low level of the related interest rate values.

The analyses presented above could be meant as an introduction to a more precise analysis on the energy trading company's risk management level. The series of assumptions and simplifications led to the indicated results. The real estimation of the recovery rate should be performed for each counterparty (there is a significant difference whether we trade with a small trading company or with a large power producer), the more suitable stochastic model for power contracts prices development should be applied as well as the stochastic model for yield curve modelling. The existence of the so-called general wrong way risk should be taken into account. General wrong-way risk is a term used to describe possible sources of positive correlation between the exposure and the probability of default. The calculation with the wrong-way risk would probably increase the CVA, which could make trading *via* an exchange more economical. A more detailed research of the CVA application in the energy sector is still required.

References

- Arlt, J., Arltová, M.** (2007), *Ekonomické časové řady*. Prague: Grada Publishing.
- Cartea, A., Marcelo, G. F.** (2005), "Pricing in Electricity Markets: A Mean Reverting Jump Diffusion Model with Seasonality." *Applied Mathematical Finance*, Vol. 12, No. 4, pp. 313–335.
- Horník, T., Drahovzal, O.** (2008), "Electro-Energetics – Managing New Risks." *Ekonomika a management*, Vol. 2, No. 3.
- Hull, J.** (2009), *Options, Futures and Other Derivatives*. 7th Ed. Upper Saddle River: Pearson Prentice Hall.
- Kiesel, R., Schindlmayr, G., Boerger, R. H.** (2009), "A Two-Factor Model for the Electricity Forward Market (February 1. 2007)." *Quantitative Finance*. Vol. 9, No. 3, pp. 279–287.
- Málek, J.** (2005), *Dynamika úrokových měr a úrokové deriváty*. Prague: Ekopress.
- Meyer-Brandis, T., Tankov, P.** (2007), "Multi-Factor Jump-Diffusion Models of Electricity Prices." *International Journal of Theoretical and Applied Finance*, Vol. 11, No. 5, pp. 503–528.
- PXE** *Rules and Regulations Power Exchange Central Europe. a.s.* Available at: <http://www.pxe.cz/dokument.aspx?k=Legislativa-PXE>
- Pykhtin, M., Zhu, S. H.** (2007), "A Guide to Modelling Counterparty Credit Risk." Global Association of Risk Professionals, No. 37, pp. 16–32.
- Witzany, J.** (2010), *Credit Risk Management and Modeling*. Prague: Oeconomica.
- Yi, Ch., Tchernitser, A., Hurd, T.** (2010), "Randomized Structural Models of Credit Spreads." *Quantitative Finance*. Vol. 11, No. 9, pp. 1301–1313.

Appendix 1

Table A1 | Detailed Characteristics of Historical Volatilities for Particular Contract Groups

Contracts type		Statistics	Volatility (%)	Margin (EUR)
BL	M	Average	0.81	4.50
		Max	2.16	
		99-percentile	1.87	
		Min	0.01	
		1-percentile	0.01	
	Q	Average	0.80	2.90
		Max	2.27	
		99-percentile	2.08	
		Min	0.01	
		1-percentile	0.01	
	Y	Average	0.71	2.70
		Max	1.38	
		99-percentile	1.36	
		Min	0.00	
		1-percentile	0.01	
PL	M	Average	0.83	7.50
		Max	2.32	
		99-percentile	2.05	
		Min	0.01	
		1-percentile	0.01	
	Q	Average	0.81	3.70
		Max	2.77	
		99-percentile	2.47	
		Min	0.01	
		1-percentile	0.01	
	Y	Average	0.82	3.50
		Max	1.55	
		99-percentile	1.55	
		Min	0.01	
		1-percentile	0.01	

Source: PXE data, author’s analysis

Appendix 2

Table A2 | Default Probabilities Calculated for the Range of the Assets over Debt Ratios and Ratio Volatility

	Volatility of the assets over debts ratio										
The assets over debt ratio	PDs	0.20%	0.40%	0.60%	0.80%	1.00%	1.20%	1.40%	1.60%	1.80%	2.00%
	1.08	0.74%	12.08%	22.02%	29.59%	34.04%	37.49%	40.93%	43.10%	44.34%	46.65%
	1.13	0.00%	2.88%	10.45%	18.64%	23.93%	28.81%	33.15%	36.20%	38.31%	41.05%
	1.18	0.00%	0.34%	4.43%	10.97%	15.93%	21.28%	26.13%	30.01%	32.60%	35.42%
	1.23	0.00%	0.06%	1.70%	6.11%	10.39%	15.47%	20.51%	24.17%	27.65%	30.43%
	1.28	0.00%	0.01%	0.59%	3.01%	6.98%	10.86%	15.75%	19.55%	23.33%	26.52%
	1.33	0.00%	0.00%	0.22%	1.40%	4.15%	7.72%	11.54%	15.87%	19.28%	22.17%
	1.38	0.00%	0.00%	0.09%	0.64%	2.48%	5.09%	8.66%	12.49%	16.09%	18.95%
	1.43	0.00%	0.00%	0.02%	0.25%	1.50%	3.48%	6.35%	9.87%	13.18%	16.26%
	1.48	0.00%	0.00%	0.00%	0.10%	0.87%	2.30%	4.83%	7.77%	10.64%	13.73%
	1.53	0.00%	0.00%	0.00%	0.03%	0.43%	1.40%	3.43%	5.98%	8.49%	11.60%

Source: author's analysis

Appendix 3

Table A3 | CVA Calculated for the Range of the Assets over Debt Ratios and Ratio Volatility for the Average Volatility of BL M Contract from Table 1, with the Average Level of the Related Interest Rates from Table 3

	Volatility of the assets over debts ratio										
The assets over debt ratio	PDs	0.20%	0.40%	0.60%	0.80%	1.00%	1.20%	1.40%	1.60%	1.80%	2.00%
	1.08	0.07	1.18	2.15	2.89	3.33	3.67	4.00	4.22	4.34	4.56
	1.13	0.00	0.28	1.02	1.82	2.34	2.82	3.24	3.54	3.75	4.02
	1.18	0.00	0.03	0.43	1.07	1.56	2.08	2.56	2.94	3.19	3.47
	1.23	0.00	0.01	0.17	0.60	1.02	1.51	2.01	2.36	2.70	2.98
	1.28	0.00	0.00	0.06	0.29	0.68	1.06	1.54	1.91	2.28	2.59
	1.33	0.00	0.00	0.02	0.14	0.41	0.76	1.13	1.55	1.89	2.17
	1.38	0.00	0.00	0.01	0.06	0.24	0.50	0.85	1.22	1.57	1.85
	1.43	0.00	0.00	0.00	0.02	0.15	0.34	0.62	0.97	1.29	1.59
	1.48	0.00	0.00	0.00	0.01	0.09	0.23	0.47	0.76	1.04	1.34
	1.53	0.00	0.00	0.00	0.00	0.04	0.14	0.34	0.59	0.83	1.13

Source: author's analysis