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Credit valuation adjustment modelling during a global low interest rate environment

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Credit Valuation Adjustment Modelling During a Global Low Interest Rate Environment

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Abstract:

The 2008/2009 global crisis highlighted the vulnerabilities and inter-dependencies in the financial system including the global over-the-counter (OTC) derivatives markets, where significant counterparty credit risk prevails. In this paper, we deal with risk under Basel III banking regulation and provide credit valuation adjustment (CVA) modelling, which is a measure of the market value of counterparty credit risk. We use simulated data to develop a stress test model to determine the impact of counterparty credit risk on bank capital regulatory requirements. We developed six scenarios of different interest rate levels and from these scenarios we computed the exposure levels and CVA. Consequently, based on CVA modelling, we estimate the impact of an interest rate hike on portfolios of the top 3 Czech banks (Česká spořitelna, ČSOB and Komerční banka) and top 3 US banks (Bank of America, Citibank and JP Morgan). We conclude that i) the analyzed Czech banks report sufficient capital buffers to withstand increase of interest rates in any scenario; ii) the observed US banks with high exposure to derivatives would face significant capital shortfalls if the interest rates increase rapidly.

Keywords: bank capital, Basel III, counterparty credit risk, credit valuation adjustment, market risk

JEL: G21, G28, G32, G33

1 Introduction

The 2008/2009 global crisis highlighted the vulnerabilities and inter-dependencies in the financial system. Systemic risk represented mainly by the interconnectedness and spill-over externalities does not pose danger only to banks but also to other financial institutions and platforms including the global over-the-counter (OTC) derivatives markets, where significant counterparty credit risk prevails. As a result, stricter regulation of OTC markets has been proposed since they might be a potential source of higher volatility and systemic risks (FSB, 2013). The two goals of the reforms including higher transparency and better mitigation of systemic risk aspire to shift default risk incurred in derivatives transactions to central counter parties (Chorafas, 2014).

However, credit valuation adjustment (CVA), a measure of the market value of counterparty credit risk, had not received much attention from regulators until the recent financial turmoil. This situation changed when BCBS (2011, p.1) stated that: *“Under Basel II, the risk of counterparty default and credit migration risk were addressed but mark-to-market losses due to credit valuation adjustments (CVA) were not. During the financial crisis, however, roughly two-thirds of losses attributed to counterparty credit risk were due to CVA losses and only about one-third were due to actual defaults.”* As a result, the issue of CVA volatility has been addressed by the Basel III regulation which is currently being implemented by banks around the world. All these facts highlight the importance of proper CVA valuation. Moreover, the over-the-counter market has been growing rapidly in the past years, which further highlights the importance counterparty credit risk that might be reduced or eliminated by the above-mentioned central counterparties.

The recent global low interest rate environment raises some important questions – what will happen to economic subjects when interest rates go up rapidly? How will financial institutions will be affected? This paper address these questions and estimates the impact of counterparty credit risk under Basel III on banking sectors in the Czech Republic and the US in case of a sudden interest rate hike. We investigate three main hypotheses: i) there is not a linear relationship between credit valuation adjustment and interest rates; ii) Czech banks do not have sufficient capital buffers to satisfy capital requirements for counterparty credit risk in case of the sudden increase of interest rates; and iii) US banks with a high exposure to derivatives will face capital shortage in case of the sudden increase of interest rates. The rest

of the paper is structured as follows: Section 2 describes the theoretical background, including a description, of the global OTC derivatives market, central counterparties and Basel III regulation. Against this background, we build a model in Section 3, where we specify the parameters, set the parameters for the computation, compute the exposure of a swap and arrive at the necessary credit valuation adjustments. Section 4 provides empirical analysis thorough scenario analysis and Monte Carlo simulations. Finally, we summarize the findings of our paper in Section 5.

2 Theoretical Background

In this section we present theoretical background for our research. First, we cover the global OTC derivatives market, then we present a definition of central counterparty and related terms such as netting and collateralization. Finally, we analyze central counterparty in the light of Basel III bank regulation that tries to minimize systemic risk of global OTC derivatives market.

2.1 The global OTC derivatives markets

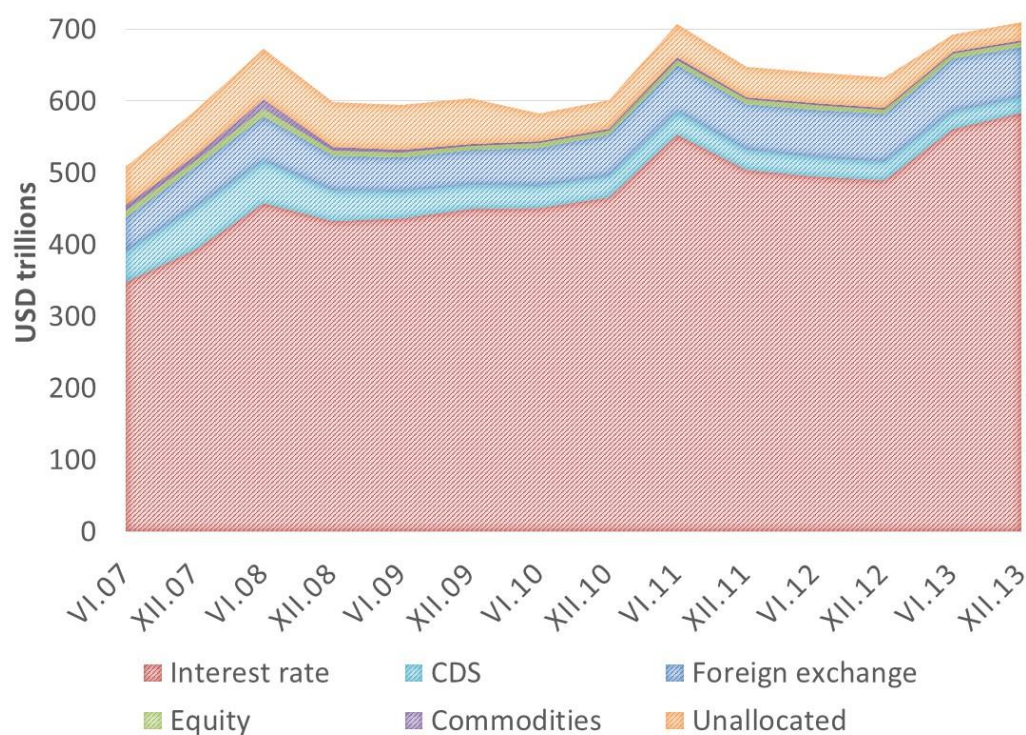
An OTC market is unregulated with respect to the disclosure of information between the trading parties. On a related note, Kalinowski (2011) highlights the amount of regulation as one of the biggest distinctions between an OTC market and trading on an exchange. Less strict criteria for trading impose higher risk on the investors and particularly on speculators that do not use derivatives to protect their core business but rather use them for high-risk speculative investments. For more details on financial derivatives and related modelling practices of credit counterparty risk we refer to, for instance, Brigo et al. (2013; 2014), or Witzany (2010; 2013).

The global OTC derivatives market measured by notional values¹ rose steadily from USD 127.5 trillion dollars 2002 to USD 710.1 trillion as of the end of 2013 (BIS, 2014). Figure 1 shows decomposition of these derivatives and displays that interest rate derivatives represented the highest share (82.3%) followed by foreign exchange contracts (9.9%), credit default swaps (3.0%), equity-linked contracts (0.9%) and commodity contracts (0.3%) as of 31 December 2013. Moreover, this figure demonstrates that the notional value of interest rate swaps saw a

¹ We argue that notional amount does not fully reflect true risk of a financial derivative. Gross market value is a better measure and is calculated *as the sum of the absolute values of all open contracts with either positive or negative replacement values evaluated at market prices prevailing on the reporting date* (BIS, 2014). For instance, gross market value of interest rate swaps oscillates around 2-4% of corresponding notional amounts, which is lower than this ratio for credit default swaps at 5-10%.

rapid year-on-year increase of 14.6% between the years 2012 and 2013. For comparison, notional value of interest rate derivatives on the global OTC market at USD 584.4 trillion as of 31 December 2013, while amounts outstanding of two equivalents of these derivatives on organized exchanges, i.e. futures on interest rates and options on interest rates, reached USD 26.0 trillion (6.9% year-on-year increase) and USD 32.8 trillion (26.6% year-on-year hike) respectively as of the same date. All these statistics further demonstrate increasing interest rate risk for both financial and nonfinancial institutions during a recent global low interest rate environment.

Figure 1: The global OTC derivatives market in 30 June 2007 – 31 December 2013 (notional values in USD trillions)



Source: Authors based on BIS (2014)

2.2 A central counterparty and systemic risk

A central counterparty (CCP) is a financial entity that is used for clearing derivatives in the OTC market. The manner in which two counterparties trade with each other in a traditional OTC transaction is called a 'bilateral trade'. There is no clearing party involved. Both of the parties are at risk from failure of each other during the life of the contract. CCP works as an

intermediary of the trade and bears the counterparty credit risk of the transaction hence it shall pay all that is owed to the non-defaulting party (Pirrong, 2011).

CCP uses variety of mechanisms and tools to mitigate and reallocate counterparty credit risk. Pirrong (2011) highlights two most important risks: netting and collateralization. Netting is a legally binding contract between two counterparties that, in the event of default, allows the transactions to be aggregated between two counterparties. In other words, transactions with negative value can be used to off-set the transactions with positive value and only the net positive value represents credit exposure at the time of default. Collateralization is another useful tool which is widely used. The exchange of collateral is a common issue for a bilateral exchange as well but a problem stems from its informality. Who, how much or when is to rise the collateral is a question that is hard to answer for trades on the bilateral basis. CCP sets the exact rules that answer these questions.

Kaya (2013) lists three main issues of the OTC markets that increased systemic risk during the global financial upheaval: limited transparency regarding risk exposures, poor risk management practices to mitigate counterparty risk and potential risk of contagion arising from interconnectedness. The new European and American regulation calls for a higher role of CCP to make the OTC market more transparent and decrease counterparty risk (Janda and Rausser, 2011). However, CCP clearing might be unattractive for many market participants since they charge fees based on bilateral agreements, and a CCP would decrease their fee income. Paradoxically, the CCP clearing might theoretically even increase systemic risk in case of a major CCP failure. To prevent this situation, CCP's access to central bank liquidity or support from other CCPs is to be clarified. If CVA is underpriced, its calculation might magnify this underpricing error through a CCP and affect other market players that can result in higher systemic risk. Both systemic risk and contagion risk are linked to payment systems, OTC derivatives contracts and extensive global interbank contracts, which result in very complex financial networks. For more details on systemic risk modelling we refer to Gai and Kapadia (2010) or Klinger and Teplý (2014).

2.3 Regulatory framework of CVA

As mentioned, the 2008-2009 global financial crisis revealed many lessons. Šútorová and Teplý (2014) stress how poor design and a low level of international coordination of financial market regulations resulted in higher regulatory efforts on banks around the world including banking

regulation Basel III as highlighted by Brunnermeier et al (2009) or Mandel and Tomšík (2011). Basel III was introduced in 2010 by the Basel Committee on Banking Supervision (BCBS, 2011) and is built on the experiences from the recent financial crisis and tries to strengthen the regulatory requirements making them simpler at the same time.² Blundell-Wignall and Roulet (2012) criticize Basel regulation, particularly its excessive complexity and ineffectiveness. Their econometric study reveals the determinants of distance-to-default (DTD), measured as a number of standard deviations away from the default point. Concerning the counterparty credit risk, Blundell-Wignall and Roulet (2012) claim that derivatives have a strong direct effect on the DTD and high levels of derivatives in banks' portfolio are often associated with greater vulnerability. We were inspired by their results in our model as discussed in Section 4.

3 The Model

The aim of the model is to assess the impact of an increase in interest rates on the capital requirements of banks. This section explains the model which will be used for calculating CVA and for testing three hypotheses stated below. BCBS (2005) issued requirements on computation of statistical measures of CVA³. For the Czech banks⁴, the mandatory requirement on CVA stems from EU regulation, mostly from Capital Requirements Regulation under No. 575/2013.⁵ This regulation clearly and obligatorily spells out the requirements for quantification of CVA, defined as the difference between the risk-free portfolio value and the true portfolio value that takes into account the possibility of the counterparty's default, and it is consistent with BCBS (2011). CVA computations are based on Zhu and Pykhtin (2007) and Alluve (2012), while insights for our model are also taken from Carlsson and Silen (2012) and Blundell-Wignall and Roulet (2012).

² For recent studies on Basel III see Chorafas (2014) or Šútorová and Teplý (2014).

³ CVA is the difference between the risk-free portfolio value and the true portfolio value that takes into account the possibility of the counterparty's default (Zhu and Pykhtin, 2007).

⁴ Banks in the Czech Republic use mainly interest rate swaps (IRS) to cover their interest rate positions. It is important to emphasize that even though banks are entering IRS trades and thus are facing counterparty credit risk, at the same time they are reducing general interest rate risk (particularly in case of an interest rate shock). The question arises how great the reduction of interest rate risk is compared to the new risk into which the counterparts are entering.

⁵ Capital Requirements Regulation (CRR) and Capital Requirements Directive under No. 2013/36/EU (CRD) were released in June 2013, commonly known as Capital Requirements Directive IV (CRD IV). Consequently, the transposition of CRD IV into Czech law is supposed to be done through an amendment to the Act on Banks until the end of 2014.

3.1 Model specification

As mentioned before, the exposure of OTC derivatives are based on future development of the swap value, so the model input will be generated by Monte Carlo simulations. There are two limitations of the model. First, it is focused only on calculating CVA plain vanilla swaps. Second, neither netting nor collateral is allowed and therefore the model cannot handle the whole portfolio together but can only consider one counterparty and one contract at a time. However, despite these limitations, we believe that our model illustrates the problems of CCR and increasing interest rates adequately. In order to compute CVA, we need to estimate the swap exposure through Monte Carlo simulations, where an estimation of interest rates of the swap has to be made. After we compute the exposure levels, the outcomes will be depicted in different scenarios as the result of the Monte Carlo simulations approach. After the different path of exposures is modeled, we can proceed to find out statistical measures of exposure: expected exposure (EE), which serves as an input for the CVA computation. In the model we focus on two other inputs: probability of default and loss given default. Consequently, we insert all these inputs in the formula for computing the CVA as required by BCBS (2011) and finally we check the validity of the following hypotheses:

1. An increase of interest rates will not influence the capital requirements of TOP 3 banks in the Czech Republic.
2. An increase of interest rates will have substantial effect on banks with high exposure to derivatives such as TOP 3 US banks.
3. There is a linear relationship between CVA and interest rates.

3.2 CVA computation

As mentioned above, CCR is the risk that the counterparty in a derivative contract will default before the contract expires and will not make the agreed contract payments. Since exchange-traded derivatives have guaranteed cash flows, only privately negotiated contracts such as OTC derivatives are subject to the counterparty credit risk. CCR is similar to other forms of credit risk with two exceptions: the uncertainty of exposure and bilateral nature of credit risk (Zhu and Pykhtin 2007). In a typical lender-borrower contract, everyone knows who the lender and the borrower. Moreover, the exact exposure (the borrowed amount) is also known. Since the exposure of a derivative contract changes over time, it can easily happen that the roles reverse. In the following sections we will discuss how CVA is computed as the price of counterparty credit risk.

3.2.1 The total credit exposure

Since the credit exposure of a derivative contract is unknown in the future, a model using specified boundaries or parameters is used to establish a framework. The exposure depends on internal factors of the trade (e.g. collateral value) as well as external factors (e.g. development of interest rates). The exposure of the bank is zero if the contract value is negative, because the bank has nothing to lose. If, on the other hand, the contract value is positive, the bank faces a positive exposure. If this is the case in the time of the counterparty default, the following three steps are to be undertaken by the bank: the bank i) closes out the position, but receives nothing from the defaulting counterparty, then ii) enters into a similar contract with counterparty and pays the market value of the contract and (iii) has a net loss that equals the contract's market value (Zhu and Pykhtin 2007). Let us now put the counterparty exposure in more exact terms. If there is only a single derivative contract in the bank's portfolio, then the credit exposure is equal to the maximum of the contract's market value and zero. If the value of contract i at time t is denoted as $V_i(t)$, the contract-level exposure is given by:

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

If there is more than one trade with a defaulted counterparty and the counterparty credit risk is not in any way reduced, then according to Zhu & Pykhtin (2007), the sum of all contract-level credit exposures is equal to the maximum loss for the bank, as in the following equation:

$$E(t) = \sum_i E_i(t) = \sum_i \max\{V_i(t), 0\}$$

To reduce the credit exposure significantly, the counterparties often use netting agreements. In such contracts transactions with negative value can offset the ones with positive value, thus the credit exposure at default is represented only by the net positive value and the total credit exposure is reduced to the maximum of the net portfolio value and zero:

$$E(t) = \max\left\{\sum_i V_i(t), 0\right\}$$

However, there can be multiple netting agreements with one counterparty. Also, not every trade is covered by a netting agreement. Denoting the k th netting agreement with a counterparty as NA_k , the counterparty-level exposure is given by:

$$E(t) = \sum_k \max \left[\sum_{i \in NA_k} V_i(t), 0 \right] + \sum_{i \in \{NA\}} \max[V_i(t), 0]$$

The inner sum of the first term represents the k the netting agreement, the outer one sums exposures over all netting agreements. The second term represents the trades that are not covered by any netting agreement (Zhu and Pykhtin 2007).

3.2.2 Statistical measures of exposure

The statistical measures defined in this section are based on BCBS (2005) and Carlsson and Silen (2012). We focus on three most widely used measures of exposure: expected exposure, potential future exposure and expected positive exposure. First, expected exposure (EE) is the probability-weighted average exposure and represents the expected loss if the counterparty defaults. EE is the average of the positive MtM-values, hence it is always larger than the average of the MtM-values. The expected exposure is defined by the following formula:

$$EE_t = \frac{1}{N} \sum_{i=1}^N \max(0, V_{ti})$$

Where

- $i=1, \dots, N$ is the number of the scenario
- V_{ti} is the swap value for i-th scenario in time t

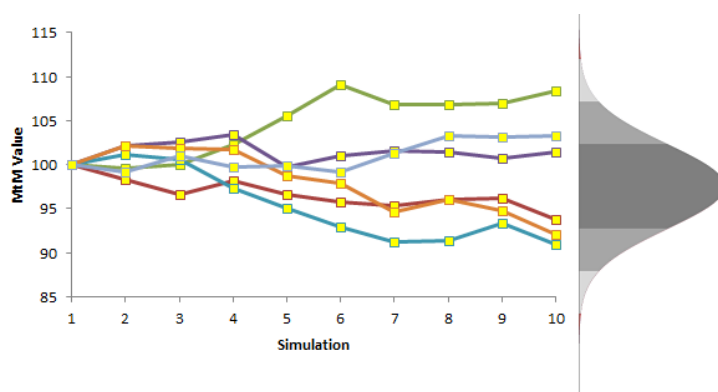
Second, potential future exposure (PFE) measures the worst possible exposure. It is the maximum exposure estimated to occur on a future date at a high level of statistical confidence (BCBS, 2005). The confidence level could be e.g. 99%. This means, that with a 99% probability the exposure will not exceed the PFE level. This measure reminds of value at risk (VaR). One of the difference between PFE and VaR is, that for PFE the time horizon is generally longer. Finally, expected positive exposure (EPE) is the time-weighted average of individual expected exposures in given time horizon. Technically we take the values of EE_t and compute the average with respect to time periods:

$$EPE = \frac{1}{M} \sum_{i=1}^M \max(0, EE_t)$$

3.3 Scenario analysis

Scenario analysis is the process of creating a set of observations of counterparty- level exposure, where each observation corresponds to one market scenario at each simulation date. Figure 2 shows the scheme of the modelling process. We can observe a different exposure for each simulation date. We start with PV = 100 and see how it evolves over time. In the end we can see the distribution of outcomes. While less than ideal, since this method only uses six different scenarios, methodologically it serves its purpose in this analysis. Normally, we use the Monte Carlo approach to generate thousands of scenarios, and then the distribution would typically appear as presented. The periods between the simulation dates are called 'time buckets'. The number of simulation dates is usually restricted because of the computational intensity required to calculate counterparty exposures. This holds mostly for banks, while they have a large portfolio of derivatives. Therefore simulation dates used by most banks usually comprise daily or weekly intervals up to a month, monthly up to a year and yearly up to five years, etc. (Zhu and Pykhtin, 2007).

Figure 2: Scheme of simulation for credit exposure



Source: Authors

3.4 Inputs to the model

3.4.1 Probability of Default

Probability of default (PD) is one of the core inputs when building a credit risk model (Gurny and Gurny, 2013). The accuracy of PD measurement has a great impact on the quality of the results of a credit risk model. PD is the probability that an institution defaults during a specified period of time and is based on both macroeconomic and microeconomic factors. Generally, during a financial crisis, when the potential of liquidity provision is low, PD gets higher across

all institutions. However, it is the question of each specific counterparty to deal with the economic downturn. There are, however, obstacles to accurately compute PD estimations. One of them is low number of defaults especially in high rating grades. Due to relatively low number of borrowers a high degree of volatility is observed even if some defaults take place in a given year. The usual banking practice for obtaining PD values consist of qualitative mapping mechanism to bank-wide master scales or external ratings (Engelmann and Ranhmeier, 2011). The approach that will be used in our model is based on BCBS (2011).

$$PD(t_i) - PD(t_{i-1}) = \exp\left(-\frac{s(t_{i-1})(t_{i-1})}{LGD}\right) - \exp\left(\frac{s(t_i)(t_i)}{LGD}\right) \quad (2)$$

where

- $(PD(t_i) - PD(t_{i-1}))$ is the probability that the counterparty defaults between t_{i-1} and t_i
- s_t is the credits spread of the counterparty at time t_i , used to calculate the CVA of the counterparty
- LGD is the loss given default of the counterparty (see below)

Basel III rules enable banks to use their internal models for credit risk and the banks have to use this formula as a component of the overall CVA valuation. If some variables are not available, e.g. credit spread of the counterparty, then a proxy has to be used. In the case of credit spread there is a substitution in the form of a proxy spread based on the rating, industry and region of the counterparty (BCBS, 2011).

3.4.2 Loss Given Default

Loss given default (LGD) is the credit loss incurred if a debtor of the financial institution defaults. More precisely, LGD is the ratio of losses to exposure at default. Three kinds of losses can occur: i) the loss of principal, ii) the carrying costs of non-performing loans, and iii) workout expenses. Three ways can be used to measure LGD for an instrument: First, market LGD is observed from the market prices of defaulted bonds or marketable loans soon after the default actually happens. Second, workout LGD is based on set of estimated discounted cash flows resulting from workout (loan repayment) and estimated exposure. Finally, implied market LGD is derived from risky but not defaulted prices of bonds, where a theoretical asset pricing model is used (Schuermann, 2004). BCBS (2011) requires LGD to be based on the spread of a market instrument of the counterparty, or if not possible use a proxy spread based on the rating, industry and region of the counterparty.

3.4.3 CVA formula

The basic definition of CVA can be written as:

$$CVA = PD \cdot LGD \cdot EAD$$

where

- the PD represents the probability of the counterparty's default.
- LGD is the loss given default, hence the percentage of what is lost if the counterparty defaults.
- EAD is exposure at default.

BCBS (2011) specifies two ways how to compute CVA capital requirement: Advanced CVA approach and Standardized CVA Approach that is defined for the banks that do not qualify for the internal EPE model. It is based on the following formula:

$$K = 2.33\sqrt{h} \sqrt{\left(\sum_i 0.5 \cdot w_i (M_i \cdot EAD_i^{total} - M_i^{hedgs} B_i) - \sum_{ind} w_{ind} \cdot M_{ind} \cdot B_{ind} \right)^2 + \sum_i 0.75 \cdot w_i^2 (M_i \cdot EAD_i^{total} - M_i^{hedgs} B_i)^2}$$

Where

- 2.33 is the standard deviation for the 99 % confidence interval
- h is the one-year risk horizon, $h=1$
- EAD_i^{total} is the exposure at default of counterparty across all netting sets
- B_i is the notional amount of purchased single name CDS hedge, which is used to hedge CVA risk
- M_i is the notional weighted average maturity
- w_i is the weight allocated to the counterparty according to external rating
- B_{ind} is the notional value of purchased index CDS
- M_{ind} is the maturity of the index hedged „ind“
- w_{ind} is the weight applicable to index hedges

The advanced CVA approach is applicable to the banks with EPE model and VaR model for specific credit risk and will be used in the model. BCBS (2011) defined the CVA capital charge as follows:

$$CVA = LGD \int_0^T P(t)EE(t)dPD(0, t)$$

where

- $P(t)$ is the risk-free discount factor for t ,
- $EE(t)$ is the risk-neutral expectation of the exposure to the counterparty at time t .

The integral can be approximated by the following sum (Alluve, 2012).

$$CVA = LGD \sum_{i=1}^k \left\{ \frac{EE(t_{i-1})P(t_{i-1}) + EE(t_i)P(t_i)}{2} \right\} (PD(t_i) - PD(t_{i-1}))$$

3.4.4 The CVA capital charge

As stated above, banks need capital to cover risks in conducting business and should follow Basel accords. The total counterparty credit risk capital charge under Basel III has two components: default risk capital charge and CVA risk capital charge:

$$\text{Total CCR Capital Charge} = \text{Default Risk Capital Charge} + \text{CVA Risk Capital Charge}$$

The default risk capital charge for CCR, which is the credit risk for conventional loans, is based on the risk weights obtained from external rating and multiplying with the outstanding Exposure at Default (EAD)⁶. The CVA risk capital charge is required for OTC transactions with unstable credit exposure. The expected exposures for the six scenarios computed in the previous section forms the basic increment in the CVA formula. The input parameters to the model are chosen according to BCBS (2011, p. 31) and summarized in Table 3.⁷

⁶ Concerning exposure at default, BCBS (2005) specifies two main ways to compute EAD for derivatives: internal model method (IMM) and current exposure method (CEM).

⁷ The values of the parameters were chosen as expert estimations of the authors based on extensive research of both empirical and theoretical studies as well as on real-world data as of September 2014.

Table 3: Parameters of the CVA model

Parameter	Value
Risk-free discount factor (P_t)	2%
Loss given default (LGD)	60%
CDS spread	10%

Source: Authors

3.5 Simulation of interest rates

To simulate the interest rate movements a Monte Carlo model in Excel was used. The model comprised 1,000 simulations, each simulation started at the 2% interest rate⁸ and increased randomly in the predefined fashion by changing the range of random numbers. We consider six different scenarios, from the mildest increase to the most severe increase of the interest rates. Table 1 summarizes these cases.

Table 1: Simulation of interest rates

95 % confidence interval of IR in Year 10	
Scenario 1	2.05% - 2.10%
Scenario 2	2.50% - 3.00%
Scenario 3	3.00% - 4.00%
Scenario 4	3.40% - 5.00%
Scenario 5	4.40% - 7.00%
Scenario 6	6.00% - 10.00%

Source: Authors

3.6 Computation of swap exposure

Let us suppose a swap contract between two banks and call them Bank A and Bank B. Bank A pays a fixed rate of 2%, Bank B pays a floating rate based on the market conditions. We assume the notional value of the swap worth USD 100 million. To compute the exposure of the swap we use the simulated interest rates of the previous six cases. For simplification, we look at the swap as if it was two bonds. Since Bank A pays the fixed interest rate of 2%, then according to the assumption of rising interest rates in all cases, it will be always in the money in terms of option theory⁹. Therefore Bank A will always have a positive exposure and therefore faces the counterparty credit risk. If we compute the market value of the swap in all

⁸ This level of interest rate corresponds to a global low-interest rate environment in September 2014.

⁹ For more information on option theory see Dvořák (2010) or Hull (2014).

the years of the swap's existence, we will automatically know the exposure of Bank A. Moreover, we assume the maturity of the swap 10 years and a USD 2 million coupon paid annually.

The exposure profile has a 'hill shape', it starts at zero and ends at zero. This is logical, because there is no uncertainty in the initiation and expiration of the swap. Somewhere in the middle of the swap life the exposure reaches the greatest value, because of the highest uncertainty. As the projected interest rates rises, the exposures rises. The highest exposure for the mildest scenario amounts mere USD 0.17 million, whereas in the most severe scenario is about USD 12.7 million. As a result, rising interest rates have a great impact on the exposure profiles. Table 2 displays the expected exposure of our swap in different scenarios. For reminder, expected exposure is computed as the average exposure in given years, in our case from the 1,000 simulations.

Table 2: Expected exposure of the swap

Maturity	0	1	2	3	4	5	6	7	8	9	10
Scenario 1	0.00	0.06	0.11	0.14	0.16	0.17	0.17	0.15	0.11	0.07	0.00
Scenario 2	0.00	0.62	1.09	1.45	1.65	1.73	1.67	1.48	1.14	0.65	0.00
Scenario 3	0.00	1.19	2.12	2.77	3.22	3.37	3.24	2.87	2.23	1.27	0.00
Scenario 4	0.00	1.77	3.17	4.18	4.78	5.04	4.92	4.35	3.36	1.92	0.00
Scenario 5	0.00	2.92	5.19	6.80	7.84	8.18	7.98	7.08	5.51	3.17	0.00
Scenario 6	0.00	4.70	8.20	10.76	12.22	12.74	12.35	10.99	8.56	4.94	0.00

Source: Authors

4 Hypotheses testing

4.1 Hypothesis 1 (nonlinearity)

In this section we deal with Hypothesis 1 that states „There is not a linear relationship between credit valuation adjustment and interest rates.“ Table 4 demonstrates that the CVA increases

more or less proportionally as interest rate increases. In the mildest increase in Scenario 1, the CVA is negligible (0.001% of the notional which makes approximately USD 1,000). In the most severe Scenario 6, however, the CVA value is 0.078% of the notional USD 100 million, which makes USD 78,000. Supposing a bank has in its portfolio more of these swaps and the total CVA is computed as a sum of each swap, then the overall CVA value should not be overlooked. Furthermore, Table 4 shows that as the interest rate increases, the CVA also increases but more rapidly than linearly. As a result, we cannot reject Hypothesis 1, which is not so surprising regarding the underlying variables and parameters in the calculation.

Table 4: Simulation of interest rates

	Interest rate	CVA
Scenario 1	2.05% - 2.10%	0.001%
Scenario 2	2.50% - 3.00%	0.011%
Scenario 3	3.00% - 4.00%	0.020%
Scenario 4	3.40% - 5.00%	0.031%
Scenario 5	4.40% - 7.00%	0.051%
Scenario 6	6.00% - 10.00%	0.078%

Source: Authors

4.2 Hypothesis 2 (Czech banks)

Hypothesis 2 states that “Czech banks do not have sufficient capital buffers to satisfy capital requirements for counterparty credit risk in case of a sudden increase of interest rates.” In our analysis we assess how the CVA capital surcharge would impact capital buffers of TOP 3 Czech biggest banks: Komerční banka (KB), Česká spořitelna (ČS) and Československá obchodní banka (ČSOB). Table 5 includes CVA input values for all three banks.¹⁰

Table 5: CVA inputs for KB, ČS and ČSOB (as of 31 December 2012)

	Capital Adequacy (CAD)	Capital* (CZK bn)	Derivatives** (CZK bn)
KB	15.8%	59.1	979.6
ČS	17.7%	83.0	618.8
ČSOB	15.6%	55.3	738.5

Source: Authors based on annual reports of the observed banks

Notes: *Consolidated regulatory capital. **Financial derivatives in nominal value, consolidated.

¹⁰ We believe that these banks represent well the Czech banking industry since their total market share on derivatives amounted to 49% as of 31 December 2012.

When putting the inputs to the model, we found out that even in the most severe Scenario 6 the CVA forms only around 0.6 percent of the banks' capital. The complete results from all scenarios can be found in Table 6. We can conclude that in the Czech Republic the banks have a solid capital base in proportion to derivatives¹¹. As a consequence, the Basel III CVA capital charge will have a small impact on the capital requirements of the researched banks. Thus the policy recommendation should follow that the use of CCPs in the Czech Republic would not have a significant impact (*ceteris paribus*). To conclude, we reject Hypothesis 2.

Table 6: CVA for all scenarios for KB, ČS and ČSOB

Scenario 1	CVA (in bn CZK)	CVA in % of capital
KB	0.0083	0.008%
ČS	0.0070	0.007%
ČSOB	0.0068	0.009%
Scenario 2		
KB	0.0830	0.082%
ČS	0.0698	0.075%
ČSOB	0.0681	0.092%
Scenario 3		
KB	0.1593	0.158%
ČS	0.1340	0.144%
ČSOB	0.1307	0.176%
Scenario 4		
KB	0.2406	0.239%
ČS	0.2023	0.217%
ČSOB	0.1974	0.266%
Scenario 5		
KB	0.3961	0.394%
ČS	0.3331	0.357%
ČSOB	0.3251	0.439%
Scenario 6		
KB	0.6085	0.605%
ČS	0.5117	0.548%
ČSOB	0.4994	0.674%

Source: Authors

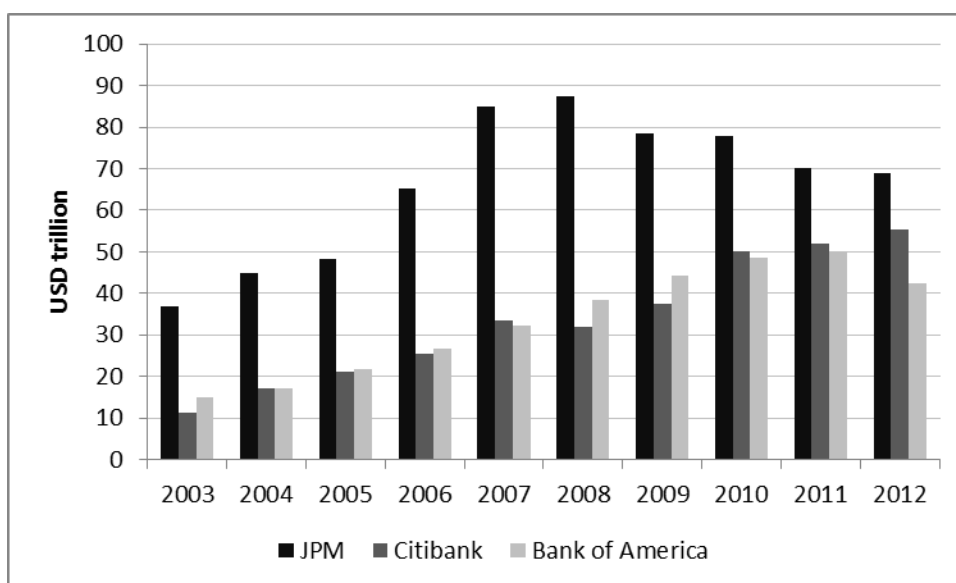
4.3 Hypothesis 3 (US banks)

To make our results more robust, we will provide a similar analysis also to TOP US banks that report significantly higher exposures to derivatives compared to TOP Czech banks, which implies their higher level of riskiness. We will focus on three of those banks that reported the highest derivative exposure: JP Morgan Chase (JPM), Citibank and Bank of America as of 31 December 2012. Figure 3 shows that JPM reported the highest exposure at USD 69.0 trillion in

¹¹ Because lack of data, we assume that all banks' derivatives exposures are OTC, thus we calculate CVA from the whole amount. We believe that such simplification does not change our results significantly.

2012, which implies a massive reduction from the peak in 2008, when its exposure exceeded USD 87 trillion. Nevertheless the exposure remains still the highest among all US banks. Citibank took the second place with the exposure over USD 55.4 trillion as of the end of 2012. The third bank was occupied Bank of America with exposure exceeding USD 42.5 trillion as of the same date.

Figure 3: Exposure to derivatives of JPM, Citibank and Bank of America in 2003-2012



Source: Authors based on Call Reports RC-L (2012)

Table 7 indicates that none of the US banks is facing any troubles in the mild Scenario 1, since the CVA represents only a fraction of percentages of the banks' capital. However, in Scenario 2 the percentage rises significantly (3.6% for JPM, 3.1% for Citibank and 1.9% for Bank of America). The percentages grow as the interest rates grows. Alarmingly, under the most severe Scenario 6, the CVA share on banks' capital increases to high levels: 26.5% for JPM, 22.9% for Citibank and 14.0% for Bank of America. If this scenario happens, these banks would face severe significant capital shortfalls, which can cause problems for all their managers, shareholders and regulators. To conclude, we cannot reject Hypothesis 3.

Table 7: CVA for each scenario for JP Morgan, Citibank and Bank of America

Scenario 1	CVA (in USD bn)	CVA in % of capital
JP Morgan	0.7	0.4%
Citibank	0.6	0.3%
Bank of America	0.5	0.2%
Scenario 2		
JP Morgan	7.4	3.6%
Citibank	5.9	3.1%
Bank of America	4.5	1.9%
Scenario 3		
JP Morgan	14.1	6.9%
Citibank	11.3	6.0%
Bank of America	8.7	3.7%
Scenario 4		
JP Morgan	21.3	10.5%
Citibank	17.1	9.1%
Bank of America	13.1	5.5%
Scenario 5		
JP Morgan	35.1	17.2%
Citibank	28.2	14.9%
Bank of America	21.6	9.1%
Scenario 6		
JP Morgan	54.0	26.5%
Citibank	43.3	22.9%
Bank of America	33.2	14.0%

Source: Authors

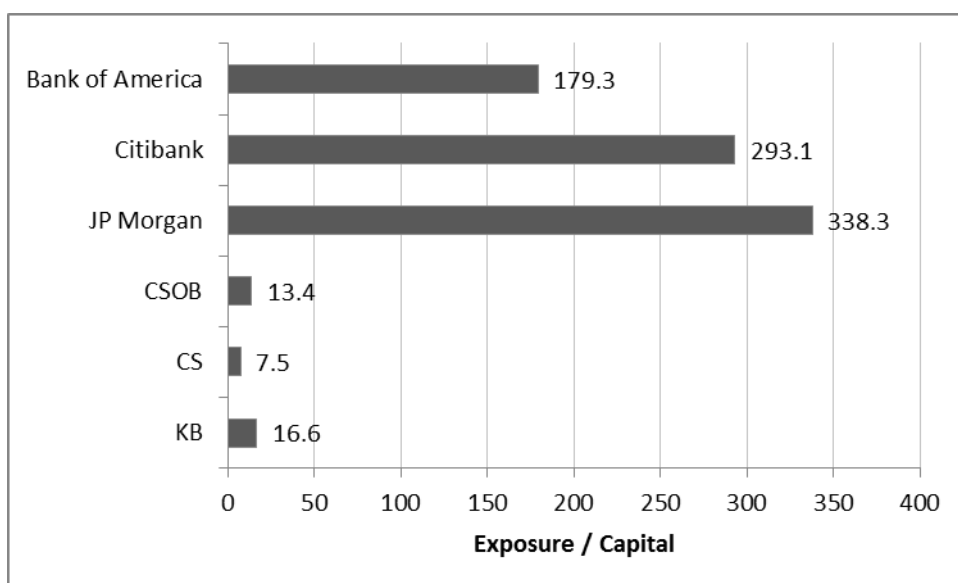
4.4 Summary of results

When comparing American banks' exposure to derivatives with their Czech peers, we reveal that the exposure of JPM, Citibank and Bank of America was more than 1.670 times higher than the average exposure of ČS, KB and ČSOB as of 31 December 2012. However, we should take into account the size of the bank's capital base to make the results more comparable. Figure 4 compares both Czech and American banks concerning their exposure to capital ratios. It indicates that the Czech banks reported their exposure to capital ratios in the range of 7.5-16.6 as of the end of 2012. However, the US banks Bank of America, Citibank and JPM reported their ratios at 179.3, 293.1 and 338.3 respectively.

Obviously, the US banks are still much more exposed to underlying risks and their corresponding demand for capital would be a lot higher than in Czech banks in case of an increase of interest rates. The results are supported by Blundell-Wignall and Roulet (2012), who found a significant relationship between derivative exposure and distance to default of a bank. We know that banks can default for many reasons apart from their exposure to derivatives. However, we remind that not Czech bank has been bailed-out during the

2008/2009 global crisis, while capital injections of the US Treasury to these three researched US banks amounted USD 126 billion.

Figure 4: Exposure to capital ratio (%) for researched banks as of 31 December 2012



Source: Authors based on banks' annual reports

5 Conclusion

In the paper we deal with counterparty risk under Basel III banking regulation through our own model on CVA modelling and test three hypotheses. We used simulated data to develop a stress test model to find out the impact of counterparty credit risk on banks' capital regulatory requirements in theory and practice. In the theoretical part, we aimed at CCPs and questioned whether the centralized clearing would help to mitigate counterparty credit risk. The CCPs are inherently too big to fail and systemically important institutions as they handle a tremendous amount of counterparty credit risk. There are pending discussions over contagion to other market players if a CCP defaults. As a consequence, the moral hazard of CCPs' management should be anticipated and reduced by targeted regulation and supervision. Moreover, we developed six scenarios of different interest rate levels and from these scenarios we computed exposure theoretical levels and CVA. Based on testing Hypothesis 1 we find that there is not a linear relationship between CVA and interest rates.

In the empirical part we estimate through CVA modelling the impact of a hike in interest rates on portfolios of TOP 3 Czech banks and of TOP 3 US banks. Based on testing Hypothesis 2 we conclude the analyzed Czech banks report sufficient capital buffers to withstand increase of interest rates in any scenario. However we argue, based on testing Hypothesis 3, that the observed US banks with high exposure to derivatives would face significant capital shortfalls if the interest rates increase rapidly.

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