Aalto University
School of Science

MS-E2177 - Seminar on Case Studies in Operations Research (V)

Attributing changes in CVA risk capital charge for OTC derivatives portfolio

Project plan

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1 Introduction

Our client is the financial services arm of a large bank. Like all its institutional peers, our client holds an ongoing portfolio of contracts (or "trades" or "derivatives") directly negotiated and signed with other financial institutions or entities. Because these contracts are not undertaken through an exchange (e.g. New York Stock Exchange, NASDAQ, etc.), they are called over-the counter (OTC) derivatives. OTC derivatives comprise a nearly 500,000 billion USD market whereas exchange traded derivatives comprise 5,000 billion USD market (2015 figures, based on outstanding "notional" values).

Because this project plan is written to be understandable by an audience who are not professionals nor students of finance (ourselves included), we will explain briefly (and on-purpose overly simplistically) the motivation behind these trades. Bank A may have made a loan L to Farmer F to expand his farm by buying a neighboring farm. The market for such loans may make it such that banks have to offer these loans at an interest rate which varies (rather than being fixed) with the Euribor [1]. Now, due to its preferences (history, strategy, style, policy, promise to shareholders, etc.) Bank A may want to have all of its income be fixed rather than variable as will be the case from Farmer F on loan L. Another bank, Bank B may have found that in aggregate income flows from variable rates are more profitable than those from fixed ones and so (or for any other reason), Bank B has decided to make it its business to pay fixed income to banks like A in exchange for taking the income from loans like loan L. Now Bank A makes more such loans than just L so if it chooses to make the "interest rate swap" agreement on multiple such loans with Bank B, the two banks have a "portfolio" of swap contracts together. Parties which enter into a contract together refer to each other as "counterparties."

Imagine further that Bank A has analogous preferences to have all of its income in its domicile currency (say Danish krone) even though its size and revenue targets motivate it to make loans to business in many, many countries in many currencies. Bank A may enter similar swap agreements with Bank B or other banks offering such swaps. Because of differing bank sizes and income flows subject to swapping preferences, Bank A will have portfolios with many other banks as will Bank B. We also want to note here that "contracts," "trades," "financial instruments" and "derivatives" are used almost interchangeably in the industry, literature and in this project plan. The term "derivative"

[1] The Euro Interbank Offered Rate (Euribor) is a daily reference rate, published by the European Money Markets Institute, based on the averaged interest rates at which Eurozone banks offer to lend unsecured funds to other banks in the euro wholesale money market (or interbank market).

is used because a financial instrument derives its price and value from the underlying currency rates and interest rates (for example; there are derivatives from other underlying values as well).

Just as Bank A was subject to some risk that the farmer might stop making payments against loan L, and even though Bank B took on that specific risk Bank A is now subject to the risk that Bank B might default on its payments against that specific contract or indeed all the contracts in their portfolio together. The entire value of the portfolio is Bank A's "exposure" to Bank B and once the probability of Bank B's default is figured in, the expected value of the lost amount is Bank A's "counterparty credit risk" due to Bank B. When an investor buys a "risky" bond, they get a discount meaning that they pay less for the bond than what the bond's nominal (stated) value is. The discount arises from the market price of the bond which takes into account the market's perception of the likelihood that the bond debt will not be paid in full because the bond-issuer will go bankrupt. Bank A does not have any such external discounting mechanism because its contracts with Bank B are private (and indeed Bank B faces a conceptually similar risk that Bank A will default).

As such, whenever Bank A considers the value of its portfolio, it reduces the risk-free value by "the market value of the counterparty credit risk" which is called "credit valuation adjustment" or CVA. The "market value" portion can be thought of (although simplistically) as follows: a portfolio by definition has multiple trades in it. Loan L may be a 5-year loan so the associated swap is said to have a 5-year "maturity". Currency Swap X may conclude after 5 years and so forth. In fact, for this reason a portfolio between a counterparty pair may be made up of very different trades. And it is not only trades that are coming in and going out of the portfolio; the underlying interest rates are changing as are the exchange rates between all the currency pairings involved in the portfolios. And the parties themselves are changing. Bank A may be growing (i.e. number of deals and amount of revenue) whereas Bank B may have defaulted on a few contracts with various counter parties. The creditworthiness of large or longstanding institutions is known [2] (in the market) and expressed as a difference (or "credit spread") from a credit worthiness of a very ubiquitous investment (e.g. German government bonds). If the credit spread of Bank B is known in this way, Bank A takes this into account when determining the market value of the counterparty credit risk due to Bank B. If the credit spread of Bank B is not known, Bank A needs to determine which known entity with which Bank B is most similar (in size, practices, etc.) and use the

[2] Rating agencies such as Standard & Poor's evaluate the credit risks of thousands of corporate issuers continuously.

credit spread of that entity as a surrogate when determining the market value of the counterparty credit risk due to Bank B.

Everything described so far would help Bank A calculate its exposure if it were looking at it today (in fact, this is the "current exposure method"). But what if the bank needed to know what the exposure would be a month or a year from now given that the interest and foreign exchange (FX) rates in the future are not known. A time-series of expected exposures are predicted in the following way. Between now and the maturity (time) of the trade furthest in the future, a simulation is done where a time-series of interest rates, a time series of FX rates and a time series of credit spreads (and any other factors necessitated by specific trades in the portfolio) are used together with details of the trades. The simulation is not just once, but dozens or hundreds of times with different series. And the time series of the different market factors are not arbitrary with respect to one another either. Instead, and using standard academic literature, "a Monte Carlo simulation framework using covariance matrices and volatility structures calibrated to historical price movements emulates the behavior of the underlying market factors relevant to the trades in the portfolio at future dates. The full simulation of these market factors together allows an accurate and consistent capturing of portfolio effects. Each transaction in the portfolio is revalued using all generated simulation paths at discrete intervals." [1]. The arithmetic mean or some other aggregation of the different simulations is used to produce a single curve (plot) of expected exposure at different future dates.

Most literature jumps to explaining that regulators require Bank A to hold some capital (i.e. and not use it to make loans or other investments) in case Bank B does default. In fact, the regulations prescribe a certain amount of capital to be held based on who all of Bank A's counterparties are and the collective impact of all the portfolios together on Bank A [2]-[4]. It is instructive to provide an example from the financial crisis of 2007-2008. AIG, a large finance and insurance company (i.e. a financial institution) made it its business (among others) to leverage its AAA (i.e. very very high) credit rating to write credit default swap contracts to counterparties who wanted default protection. Perhaps this had not been an issue under prior market conditions where counterparties made more conservatively selected loans to home-buyers. But prior to the crisis, counterparties were making loans to home-buyers insufficient or even no incomes, jobs or assets (thinking that the risk had been mitigated using Collateralized Debt Obligation tranches). When the housing prices fell due to and causing further foreclosures, AIG could no longer make payouts to counterparties, the U.S. government decided to bail out AIG in order to prevent the bankruptcies of counterparties (and the ripple-effect bankruptcies of further counterparties who were doing trades with the counterparties dealing directly with AIG) [6]. Which is an example of why regulators have required setting aside of capital for CVA risk (CVA risk capital charge).

There are many alternate ways allowed by the regulations [5] for Bank A to calculate the risk capital charge and there are many allowances for Bank A to avoid holding certain portions of the capital by buying "hedging" investments or protections (e.g. other OTC trades). Because Bank A would rather be making more loans and investments, it does not want to hold more capital than is necessary (or regulated) for CVA risk. When the need for CVA capital goes up between one assessment date and the next, Bank A would want to know what market factor (e.g. interest rates, FX rates, credit spreads) changes accompanied the rise in CVA risk capital charge.

2 Objectives

Like Bank A, our client wants to be able to attribute rises in CVA risk capital charge to market factors. While the client has practices for doing this in a top-down manner, the client representative sponsoring our project is interested in our approach to the attribution at single-counterparty level. We have to create a model ourselves of the credit risk due to a derivatives portfolio consisting of foreign exchange (FX) forwards, FX swaps, interest rate (IR) swaps and cross currency swaps that the client would have with single counterparty.

We plan to extend our model of the counterparty credit risk to calculating the associated CVA risk capital charge. This is not trivial because the regulator-approved way in which the client does this is quite complex (as described in the task section and may require us to build a model for ourselves on this as well in order to be able to relate the capital charge directly back to the market factors for trade value and risk.

Our plan is to implement the model in python and provide it in an easy-to-use Jupyter Notebook. The client would then use the notebook to visualize which market factors (and by what extent) have accompanied a change in the counterparty risk level (and associate capital charge) between one date and a subsequent date due to a portfolio, a single trade in the portfolio or some subset of trades in the portfolio. Figure 1 illustrates what the visualization could look like.

If the introduction and objectives sections have given the impression that this is a simple project, then we have done an effective job of making the project understandable. However, the tradeoff is that by not sharing the equations, calculation processes between a single derivative value to the risk capital charge and the non-linear relationship between the market factors and netting sets of trades at this point, we have belied the overwhelming complexity and downright difficulty of the project which we will attempt to express in the Tasks and Risks sections.

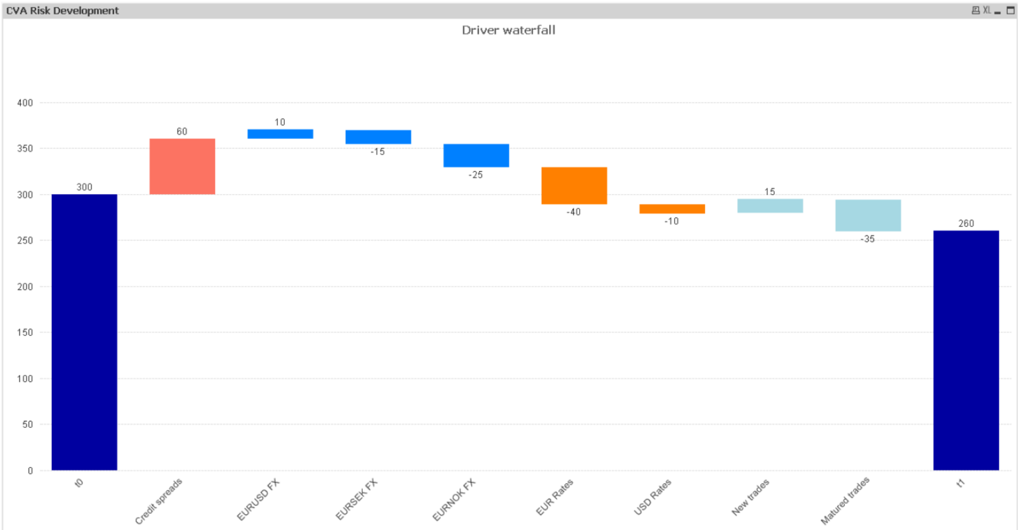

Figure 1: The Jupyter Notebook-tool will present both graphically and in tabular format the amount of change in the counterparty risk attributable to each market factor (values are illustrative only and the interest rate factor is not shown).

3 Tasks

Figure 2 shows our framework for managing this project. As the project progresses, there will be greater granularity to the tasks and many new line items will be added but we think they will fall under sub-tasks to in the categories defined in this framework.

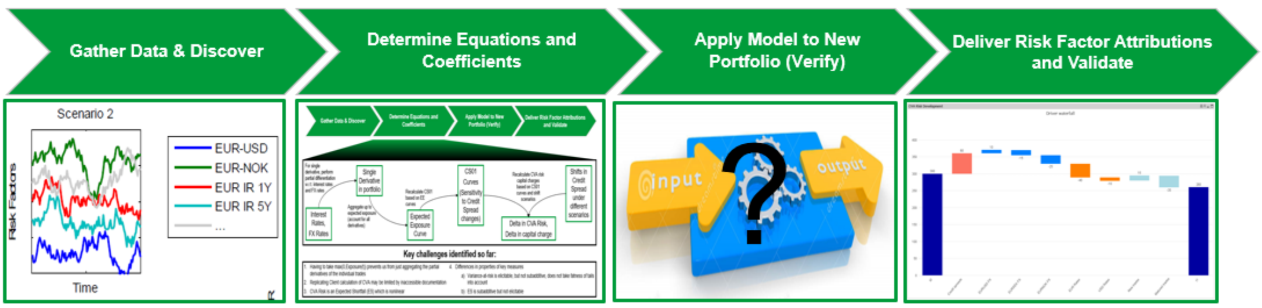

Figure 2: Framework for managing the CVA risk project.

A1. Gather Data & Discover (in Collaboration with Client Representative)

We have been meeting with the client representative regularly to gather input and example data and iteratively converging on the scope of the project. We have received an example portfolio from a specific anonymized counterparty and details of the individual trades which make up that portfolio. The client has their own simulation engine(s) to simulate future scenarios and based on randomized selection of some of those scenarios and averaging of the portfolio value under the selected scenarios, the client representative has provided us an Expected Exposure (EE) curve due to the portfolio at future points.

We have received calculation of the risk capital charge by some party in the client's own organization. Because this is the capital that the client has to set aside due the risk cause by the portfolio, the calculation is done at the portfolio level and cannot be used for the granular bottom-up attribution we are trying to achieve. The client representative has also provided sensitivity to shifts in the credit spread (credit worthiness of the counterparty). Again, this is sensitivity at a portfolio level so may have to build up our own sensitives at a trade level.

The client representative has provided extensive historical data on credit spread shifts for the counterparty (both "stressed" data from era of the financial crisis and recent historical data for a rolling number of days. Lastly, we have been gathering data on the market conditions interest rates and FX rates. We have been and will continue to visualize the data for intervening verification that our understanding of the data is correct. We have also used this method to identify gaps in the data which the client representative has been working to fill. We have also, together with the client representative, identified gaps in the client documentation which is also something that the client representative is trying to fill.

Responsibilities: Everyone

A2. Review Literature

Reviewing client and regulatory documentation has been helping us identify the topics on which we need to review texts, academic and industry publications on commercial banking risk management and measuring counterparty credit risk for trading products. We continue to supplement our understanding in this way beyond this phase as necessitated by subsequent phases.

Responsibilities: Everyone

A3. Plan Project

Gathering data, documents and understanding from literature has been informing the formulation of our tactical project plan in terms of background, objectives, tasks, schedule, resources and risks.

Lead: Oskari

B1. Determine Equations and Coefficients

We need to find out how the market values for each instrument type are calculated. With this information we can calculate the change in counterparty risk at the individual counterparty-level by summing the changes in the risk associated with each individual trade in the portfolio. The mathematical methods for this will be selected closer to the model construction. The working hypothesis is that we will use Taylor approximations including terms in respect to each market variable. Figure 3 graphically depicts this phase.

Responsibilities: Everyone

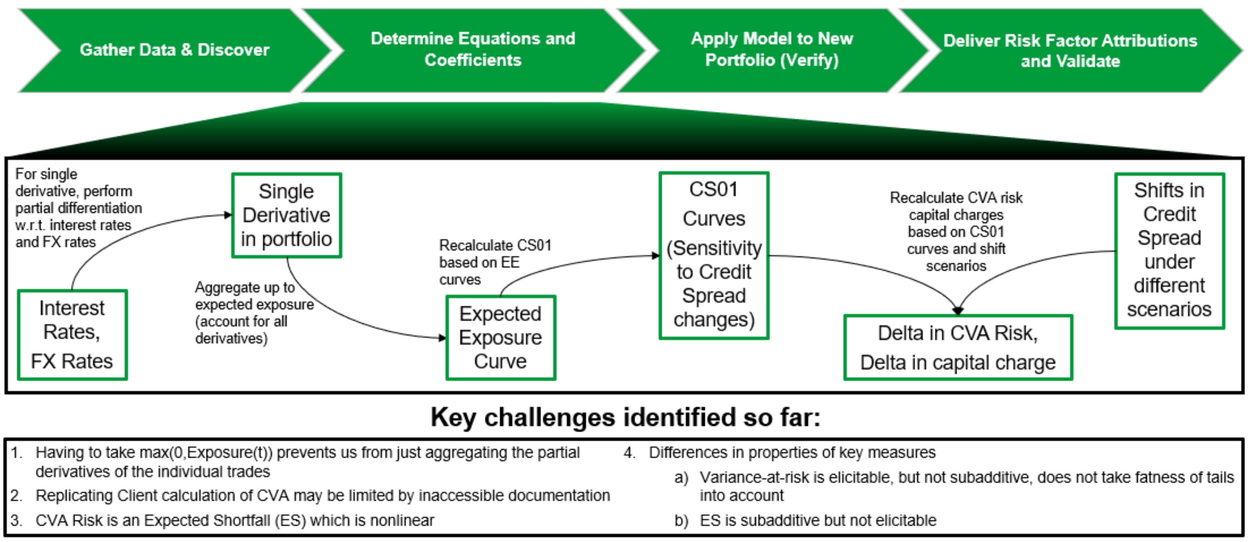

Figure 3: The methodology behind CVA calculations.

B2. Construct the Model

Based on the architecture, we will build the actual model in Jupyter Notebook. This will pull the data provided by client and it's going to include all the code for the formulas and methods. The user interface will also be built in Jupyter Notebook so the client can load alternate data in the future and view the resulting waterfall visualization.

Lead: Atte

B3. Apply the Model to the Provided Portfolio

We will apply the model to the portfolio provided by the client representative. At a portfolio level, we may be able to compare the risk changes predicted by our model with those calculated by the client (as discussed in under task A1 above).

Responsibilities: Oskari

B3. Write the Interim Report

Per the requirement of the course, we will use an interim report to provide status of the project April 10th and present it on April 12th.

Responsibilities: Everyone

C. Apply Model to New Portfolio (Verify)

As discussed, the client representative has provided a limited portfolio of derivatives for us to use in building the model. The client representative will also provide data on a simulate (potentially larger) portfolio of derivatives as well as time series of interest rates, currency exchange rates and other market variables. The simulated portfolio will be chosen such that it will be known increase in risk when, for example , the USD gets stronger. Our model should correctly indicate the direction of the risk change. We still have to determine how and if we will be able to validate the quantity of risk increase which will be indicated by our model.

Responsibility: Oskari

D. Deliver Risk Factor Attributions and Validate

The final deliverable will be a treatise on the sources cited and the mathematical methods used in constructing the model. It will also be an open-science style deliverable bringing together the example portfolio data and model so the client representative can reproduce our results as well as replace the inputs with new data to perform similar analysis. (Use of the model of course will be restricted to the client per the non-disclosure agreement the team had to sign.) The visualization will be included, but with the help of the client representative, we also aim document validation (comparing our results to the clients results under current state methods) in the final paper. We will recommend suitable use cases, but also provide caveats and explore the limitations of our model and the next steps the client representative and his organization can take to enhance the model and address those limitations.

Responsibilities: Everyone

4 Schedule

As discussed, gathering data, having collaborative working sessions with the client and literature review are the activities we have been able to do by the project plan deadline of 27.2, but these activities will have to continue. However, we plan to complete the methods determination, model construction and application to the provided portfolio in time for the interim report on 10.4. By that point we hope to finalize the details of a new portfolio with the client representative so that we can also apply the model to that portfolio as a verification step. Moreover, we hope to have settled on the client representative's own calculations of CVA risk and capital charge using the client's current state methods to include those in the final deliverable on 15.5. Figure 4 shows the schedule.

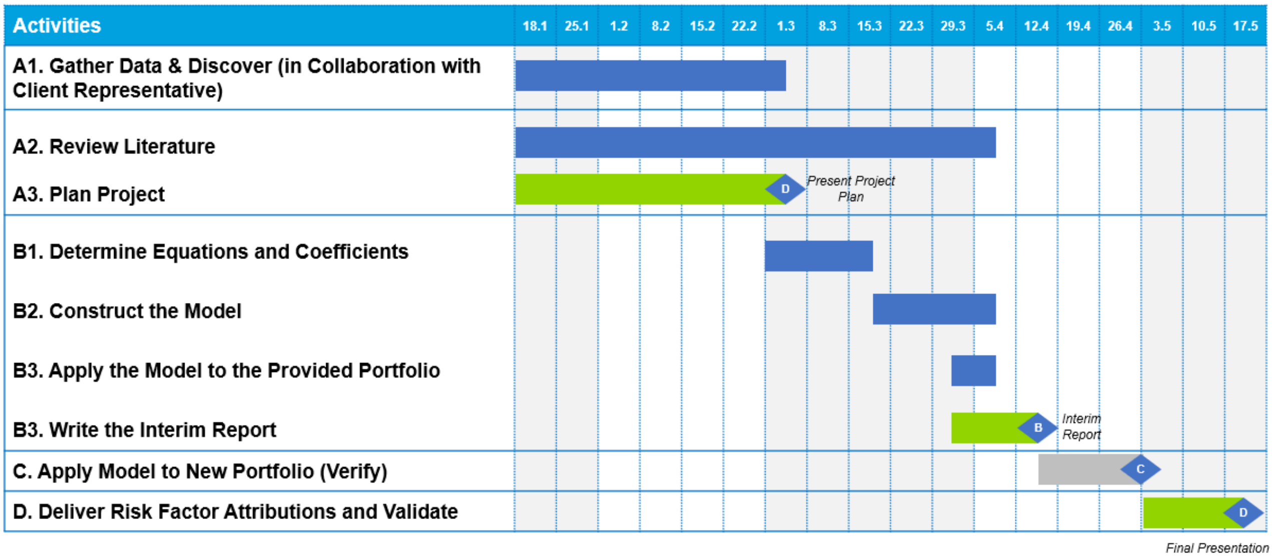

Figure 4: The schedule for the project.

5 Resources

This project team members are Oskari Kivinen (project manager) and Atte Mäkelä. Oskari is very interested in financial instruments and Atte is interested in attribution. As has already been discussed extensively, we have been meeting frequently with the client who has been a valuable advisor as well. This helps greatly not only because the data is disparate but also because we are all new in the financial field.

Professor Ahti Salo has been providing us guidance from this course and we have also consulted Ruth Kaila, the teacher of Financial Engineering (I and II). We will also form our theoretical basis on texts, academic and industry publications on commercial banking risk management and measuring counterparty credit risk for trading products and relevant regulatory documents.

6 Risks

Figure 5 shows the different risks the team is believed to tumble upon if countered. More detailed explanations below.

Risk to project success	Probability	Effects	Preventive actions	Mitigating actions
Client Data Incomplete **Client Documents inaccessible due to restrictions**	Yellow (Likely)	• Results may not tie as expected • Replicating Client calculation of CVA may be limited by inaccessible documentation • Increased workload to generate own data based on "toy model" (e.g. for Monte Carlo)	Adjust client expectations on verification and validation methods	• Use simulated data and make assumptions where necessary • Establish alternate (analytical means of validation) • Provide very specific guidance on how client can alter/extend model in-house with completed data, implementing secret documentation
Having to take max(0,Exposure(t)) prevents us from just aggregating the partial differentials of the individual trades	Red (Very Likely)	• Aggregation may not be feasible in our timeline	• Explore alternatives for aggregation	• Proceed with taking negative exposures if necessary • Document limitation or inaccuracy and advise on next steps for client
Non-linearity of CVA risk limits usability of linear approximation	Yellow (Likely)	• Non-linearity of CVA risk limits usability of linear approximation	• Adjust client expectations on efficacy of linear approximation	• Explain limitations • Identify use-cases where approximation usable
Differences in properties of key measures **Variance-at-risk is elicitable, but not subadditive, does not take fatness of tails into account** **ES is subadditive but not elicitable**	Red (Very Likely)	• Results may not tie as expected	• Adjust client expectations on verification and validation methods	• Pick one measure and follow through with analysis even if it does not tie • Explain limitations
Team member absence or inactivity	Gray (Already happened)	• Project is delayed, • Workload grows for other members	• Agreed commitment to the project • Personal healthcare	• Redistribute workload • Adjust schedule • Down-scope if possible

Figure 5: Our project is on topics which are very difficult even for professionals in the field. These risks refer how the team might bump on to them.

Client Data Incomplete and Client Documents Inaccessible due to Restrictions

As with practically any data project where the stakeholder is not also the data analyst or time is not unlimited, we have some gaps in data. However, given the secure nature of the project and the separation of responsibilities that exists by design at the client's organization, we may have to get creative to get around the incomplete data and incomplete documentation we encounter from the client. The client representative, of course, is very interested in having this project be successful so we expect to receive plenty of help with the creativity. Where data gaps persisted, we will have to use simulated data and where documentation gaps persist, we will have to make assumptions. This will cause result not to tie exactly with client data on CVA risk. As such, we will have to establish alternate (analytical means of validation). Lastly, with the deliverable, we will provide very specific guidance on how client can alter/extend model in-house with completed data, implementing secret documentation.

Having to take max(0, Exposure(t)) prevents us from just aggregating the partial derivatives of the individual trades

For the exposure of the total portfolio to be a continuous function, we would have to have parts of it fall below zero even though the prescribed definition ignores all negative exposure. This makes it infeasible to do summation of the partial differentials of the individual trades. As such, we will have to investigate alternate means of aggregation (through literature search) or proceed with including negative exposures if the project deadline so requires. We will document the limitations of our decision and advise as to next steps the client should take.

Non-linearity of CVA Risk Limits Usability of Linear Approximation

Our working hypothesis is that a linear approximation is effective for normal market conditions and the non-linear effects only take place under extraordinary conditions. We will have to adjust client expectations on efficacy of linear approximation, explain the limitations and identify use-cases where approximation is usable.

Differences in properties of key measures: Variance-at-risk is elicitable, but not subadditive, does not take fatness of tails into account; ES is subadditive but not elicitable

Because we have different key measure involved, we may have to pick one measure and follow through with analysis even if it does not tie and possibly try with the other key measure as well if feasible. In either case, we will have to adjust client expectations and explain limitations.

Team member absence or inactivity

We have discussed the commitment of each team member to the project and learned one another's schedules. However, on the outside chance that a team member is absence or inactive, we risk delaying the project and increasing the workload on other team members. In such a case, would have to request more time or else a down-scoping of the project (e.g. attributing changes in expect exposure rather than changes in CVA risk capital charge). Unfortunately this risk, which we at first estimated to be very unlikely to happen, has already realised itself. Two members of our team have - as of writing this - just left the project. We have started the mitigation actions and redistributed the tasks within the project group between the two of us left.

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