Simulation in Counterparty Credit Risk

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Overview

What is CCR?

- Chrimata Bank enters into a contract with ABC Corp.
- ABC will pay Chrimata Bank 1bn EUR in exchange for 1.2bn USD in 1 year's time.
- The exchange rate changes, and 1bn EUR is now worth 1.4bn USD.
- So Chrimata bank has made $200m profit. The transaction is *in the money*.

What is CCR?

- But what if ABC Corp can't pay?
- This is counterparty credit risk. The risk due to a counterparty to a derivatives transaction not being able to meet their obligations.
- Note that both parties have counterparty credit risk. If the exchange rate moved the other way, then ABC Corp would stand to lose from a Chrimata Bank default.
- We might try to mitigate this with netting and collateral.

Collateral

- ABC Corp could pay the $200m on the day the exchange rate changes, rather than wait until the contract matures.
- This is known as *marking to market*. The transaction is settled each day, so at any time we only have one day's worth of counterparty credit risk.
- This is standard practice with large institutions trading derivatives.

Netting

- We might have two different trades with the same counterparty, one in the money and one out of the money.
- If we have a *netting agreement* with this counterparty, then in the case of a default we can offset the losses from them not fulfilling our in the money transaction with the out of the money transaction.
- Without a valid netting agreement, we would have to pay where we owe the client, and be treated the same as any other creditor where they owe us.

Quotes from Basel II Legislation

Definiton of CCR

The counterparty credit risk is defined as the risk that the counterparty to a transaction could default before the final settlement of the transactions cash flows. An economic loss would occur if the transactions or portfolio of transactions with the counterparty has a positive economic value at the time of default.

CCR is bilateral

Unlike a firms exposure to credit risk through a loan, where the exposure to credit risk is unilateral and only the lending bank faces the risk of loss, the counterparty credit risk creates a bilateral risk of loss: the market value of the transaction can be positive or negative to either counterparty to the transaction

Exposure

We need to know not only how much our counterparties owe us now, but how much they might owe us in the future. We use Monte Carlo simulation to simulate a large number of different scenarios that the markets might take, and consider our exposure in each of these scenarios.

Definition (Exposure)

Exposure is how much we are owed at a given time. That is the larger of zero and the sum of the mark to market of all our transactions with the counterparty.

Definition

Expected Exposure on a given date is the average exposure across all scenarios at that time.

EEPE and EPE

Definition (EPE)

Expected Positive Exposure or EPE is the time weighted average over the first year of the expected exposure curve. $\mathrm{EPE} = \int_0^T EE(t)dt$

Definition (EEPE)

Effective Expected Positive Exposure or EEPE is the equivalent of EPE, but defined on a non-decreasing version of the EE curve. $mathtt EEPE = \int_0^T \mathtt{max}_{0<j<T}(EE(j))dt$

In order to model future CCR, we need to generate possible future market conditions, and we need several features to make our models realistic

- Calibration - the model's outputs must reasonably reflect what has happened in the past.
- Correlation - if different assets' prices tend to be correlated in the real world, we want them to be correlated in our simulations also.

Brief description of our model

We will build a model for a counterparty that has some foreign exchange transactions over the next year.

- We will assume that the FX rates we are interested in follow a lognormal random walk with zero drift (that is, log returns of FX rates follow a Gaussian random walk).
- We will base the volatilities of these rates on historical data
- We will base the correlations between our FX rates on historical data
- We will assume that interest rates are *zero* throughout the rest of this course

Why Log Returns?

Why do we model log returns and not prices directly (or just returns?)

- With normally distributed returns, or normally distributed prices, you can get negative prices.
- Stability of distribution over time. If returns in one time period are normally distributed as a fraction of prices, returns in the next time period are not.
- Addition of small numbers is numerically stable
- Mathematical convenience ($e^x = \int e^x \, dx$)

Lognormal Random Walk

The first part of building our CCR calculator will be to simulate a single FX rates as a lognormal random walk using historical log returns to determine the standard deviation.
We will assume that FX rates demonstrate zero 'drift'. That is, the mean log return is zero.

Cholesky Decompositiion

One of the ways in which we want our model to resemble reality is that we want *correlations* between risk factors to be preserved. That is, if two things are correlated in our historical data, we want them to be correlated in our simulation.

Definition (Cholesky Decomposition)

The **Cholesky Decomposition** of a positive semi-definite matrix M is a lower (upper) triangular matrix L (U) such that $LL^T = M$.

Cholesky and Correlation

Given a random vector X which consists of standard normal random variables, we can obtain a set of random variables with a given correlation matrix Q by multiplying X with the Cholesky decomposition of Q. Note that the covariance matrix of X is the identity matrix I by construction. Then we have:

$$\begin{aligned}
\mathbb{E}\left(ZZ^T\right) &= \mathbb{E}\left((LX)(LX)^T\right) && (1)\\
&= \mathbb{E}\left(LXX^TL^T\right) && (2)\\
&= L\mathbb{E}\left(XX^T\right)L^T && (3)\\
&= LIL^T && (4)\\
&= LL^T && (5)\\
&= Q && (6)
\end{aligned}$$

Marking to Market

As we have seen the counterparty credit risk of a trade increases over its lifetime.
One way to help mitigate this is 'marking to market'. Say we have a contract to buy 1 million barrels of oil on June 30 for \$50 per barrel. The current price of oil on June 30 is \$60 per barrel. So we expect to make \$10m profit.
But what if the counterparty doesn't have 1 million barrels of oil on June 30? Then we don't get our \$10m.
This is where *collateral* comes in. If we have a collateral arrangement, the client pays us \$10m now, and we reduce the counterparty credit risk.

Collateralised Risk

So if we have a collateral arrangement, do we still have counterparty credit risk?
Yes, because it takes time to mark trades to market, and also takes time to replace the trades that the client will not fulfil, so the price of the replacement trades will not be the same as the price of the original transactions.

Definition

The *Margin Period of Risk* is 'the time period from the most recent exchange of collateral covering a netting set of OTC derivative contracts with a defaulting counterparty until the OTC derivative contracts are closed out and the resulting market risk is re-hedged'.

Margin Period of Risk

To model collateralised counterparty credit risk, we take the *difference* in exposure between today and the last time the portfolio was marked to market.

Definition (Collateralised Exposure)

$$EE(t) = max(MTM(t) - MTM(t - MPR), 0)$$

Collateralised exposure is effectively a measure of the *sensitivity* of the value of the portfolio, rather than the value of the portfolio itself.

Model performance

- Individual trades and a single currency pair simulations don't represent the ongoing performance of our models.
- The model can be used for front office, accounting or risk pricing.
- Bad models lead to incorrect results and provide a false sense of security.
- The Black-Scholes option pricing model provided an advantage to Long-Term Capital Management L.P. (LTCM) ... until it collapsed.
- There are lots of other stories like that through the years.
- How to tell if your model is fit for purpose?

Model assumptions

- Our FX simulation model doesn't take into account of interest rates, inflations/deflations, the liquidity of the market, premium and fees, etc ...
- It cannot be applied to managed and pegged currencies either.
- There is no drift in our model.
- Cross-currency pairs are not directly simulated.

Model monitoring

- Backtesting frameworks are ways of testing predictive models.
- We can backtest new models before using them in the real world to test if the model can be used.

Definition (Backtesting)

Backtesting is part of the quantitative validation of a model that is based on the comparison of forecasts against realised values.

Definition (Validation)

Validation is a broader term that encompasses backtesting, but can be any process by which model performance is assessed.

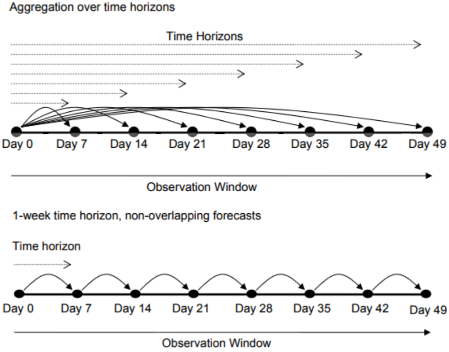
What should be backtested?

The questions we should be asking are:

- How did our cross-currency simulations capture the realised FX rate changes? We need to backtest our FX simulations.
- Are our trade simulations performing as they should? We need to backtest our trade simulations.
- Do our netted portfolios capture all the risks faced? We need to backtest our portfolios.

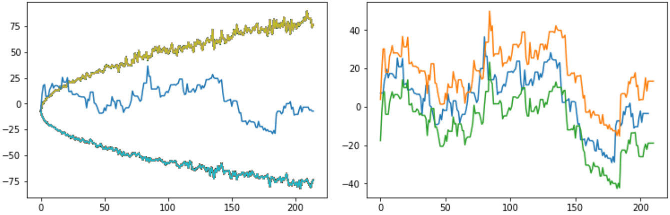
Types of backtesting

Types of testing that can are common practice [BCBS185]:



Exception counting

The simplest way of backtesting is counting the number of times we have breached certain percentiles.



If the count of exceptions is too high, it is a sign that the model is not performing.

Further backtesting

- Counting exceptions works to highlight issues.
- For Market Risk, it is enough to count exceptions and apply a regulatory capital add-on.
- For counterparty credit risk, it is not enough:
  - It doesn't show us if our model managed to capture the realised rates or prices correctly or if it was overconservtive.
  - When there is an exception, it doesn't show us by how much the model failed to capture the realised rates or price.
- To resolve that [BCBS185] says we should backtest p-values based on quantiles.

References

BCBS185
Sound practices for backtesting counterparty credit risk models (December 2010)
(https://www.bis.org/publ/bcbs185.pdf)

The End