Financial Simulation Term Project

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Project Overview

This document outlines the term project for Financial Computaton & Simulation for the Spring 2021 semester. The project description is given in the first section and a list of deliverables and milestones is given in the second. Key deliverables include a written project report due during finals week (exact date TBD) and a group presentation given via Webex during the last week of classes by **noon on Friday, April 30, 2021**. This is a group project and groups must consist of 2-4 students. You are allowed to use any programming language for the project (Matlab, R, Python, etc.) but all students in each group are responsible for knowing the details of all aspects of the project. R in preferred because all students should be familiar with it, but you can use a different language if you want. All students must participate in the project and the final report will have a section outlining each team member's contribution. Your grade will be heavily influenced by the organization and clarity of your presentation and report. In other words, the output of the project is expected to be professional.

*Submit the report via LMS.

1. Project Description

You are in charge of a large portfolio of equities and options at a major financial institution (FI). Being a large FI, you have have the ability to short stocks and/or stock options (meaning that you can write them). As such, your manager has tasked you with designing a simulation to test a hedging strategy. Your strategy must ensure that your portfolio stays within the following risk limits:

1. You must maintain a strict 10-day 99% Value-at-Risk (VaR) of 3% of the value of your portfolio. In other words, you expect to lose no more than 3% of your portoflio value over a 10-day period.
2. Your portfolio is self-funding, meaning that your investment capital comes from option premiums.

The main deliverable from this project is a simulation program. Your simulation must meet the following criteria:

1. For simplicity, you can design and simulate your strategy using various options on a single underlying stock but it must be ameanable to taking in realistic parameters (e.g., stock volatilities, expected returns, etc.).
2. Your simulation must be able to handle writing both put and call options.
3. Your simulation needs to account for trading costs in a reasonable manner (we will discuss this in more detail in the coming weeks, but you could for example, consider variable costs for equities).
4. Your goal is to simulate the overall performance of your hedging strategy subject to the above constraints.

Deliverable 1 - Performance Goals and Metrics

The first task is to define your strategy. I recommend using a Delta (or Delta-Gamma) hedging strategy to manage the risk of your option portfolio. That is, for a given option, you need to buy and/or sell the underlying equity at discrete intervals to maintain you risk limits. At this point, a basic overview of the strategy is fine.

Once you have clearly defined your strategy, you need to define performance metrics to objectively assess your fund's performance. These metrics should be used evaluate the expected performance of your portfolio. Examples of common metrics include Sharpe Ratios, overall volatility, and value-at-risk (VaR).

You also need to describe any data you will be using. For example, you might want to use U.S. Treasury data for interest rates or some historical stock data to calibrate your models. Note that all data will need to be submitted to me as part of the report but for this step you only need to describe the data and the source(s).

Deliverable 2 - Modeling Asset Prices

The first step in building a hedging strategy is to build suitable models for asset prices. In so doing, you must compare a minimum of two different models for the underlying stocks. One of the models should be Geometric Brownian Motion (i.e., the model underlying the Black-Scholes (B-S) equations) that we will cover extensively in class. It is up to you to decide on the other model(s). For example, you could include time-variation in the drift or diffusion terms or use a model such as a jump-diffusion model (again, several viable models will be covered in class). In any case, you must clearly define the models and why they are chosen (the justification for the B-S model is that it is a well-known benchmark).

You do not need to fully calibrate the models to real data. However, you should design your simulation study such that it can take in a range of reasonable parameters (e.g., iterest rates, expected stock returns, stock volatilities) so that it can be used to simulate a variety of assets. For example, you may want to look at the expected returns of several stocks in the S&P 500 to get an idea about historical returns and volatilities.

Deliverable 3 - Hedging Strategy

Once you have a suitable function (or functions) for modeling asset prices, the next step is to write a function to implement your hedging strategy. In this step, you will need to consider the following:

1. How will you model option prices? You need to decide at what price you will sell the options to fund your investment.
2. How will you estimate delta? Note that this depends on the types of options your code can handle.
3. How often should you rebalance your portfolio?
4. How should you model transactions costs (Delta-hedging involves periodic purchases and sales of stocks which can be expensive if done too frequently)?
5. What types of options are you going to to permit? Your code MUST be able to handle European-style puts and calls.
6. **Model Enhancements**: In addition to the above requirements, you can consider enhancing your model to include the following options:
   (a) American-style options.
   (b) Barrier options.
   (c) Basket options (i.e., options written on multiple underlying assets - note in this case you would have to model correlation between the underlying assets).

Note that any of the above model enhancements will have a positive influence on your grade if successfully implemented. My suggestion is to get the basic simulation working first, and then try to expand your code to handle at least one of the model enhancements.

Deliverable 4 - Presentation

Each group will present by noon on Friday, April 30, 2021 to the instructor via Webex. Each group member must participate. However, participation is **not** restricted to speaking. For example, helping to put together the slides is a form of participation. The goal of the presentation is to explain your model including key assumptions and limitations along with the results. The presentations should be about 15 minutes and each group will book a 30 minute Webex meeting so I can ask questions.

Deliverable 5 - Written Report

The final deliverable is the written report. You are encouraged to submit a draft to me prior to submitting the final version. Note that plagiarism will not be tolerated and will be viewed as a violation of academic integrity. As such, if you have questions about what constitutes plagiarism, please submit them to me *prior* to submitting the final report. There are no length requirements for the report; but it should include a 1-2 page executive summary of the overall results followed by a detailed report that supports your conclusions.

Finally, **the final report should include a description of each group member's key contributions to the project.**

2. Milestones

Due Dates for the Deliverables

1. April 5. Deliverable 1.
2. April 19. Deliverable 2.
3. April 26. Deliverable 3.
4. April 30. Deliverable 4.
5. Finals week. Deliverable 5. This is the final report and all materials should be submitted as a single report. All code and data should also be submitted as attachments. The exact due date for the final report will be based on the final exam schedule.

Grading

The project is worth 50% of your final grade. Grades are based on group and individual performance. The individual performance portion of the grade will be assessed as an ex post assessment to the group grade. The first three deliverables are "all or nothing" meaning you must submit them by the due date to receive the points. Specific instructions will be given for each deliverable. The purpose of these deliverables is for me to provide interim feedback on each step. The breakdown of the grades for each deliverable will be as follows:

1. Deliverable 1. (2 points)
2. Deliverable 2. (5 points)
3. Deliverable 3. (5 points)
4. Deliverable 4. (10 points)
5. Deliverable 5. (28 points)