MATH80626 – Teamwork

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Informations importantes

- Ce travail vaut pour 20% de la note finale.
- Ce travail doit être fait en équipe de 3-4.
- Je ne réponds qu'aux questions posées sur le forum.
- Votre fichier Rmarkdown ou R Notebook devra être déposé sur la boîte de dépôt prévue à cet effet au plus tard à la date fixée.
- Documentez clairement la totalité de votre code R. Celui-ci doit être compilable.

Context

You work as a quantitative analyst for a large investment bank. You and your team are responsible for challenging the models used by traders and risk managers. You work with R and love reproducible research. All your files are written in Rmarkdown or R notebook.

You can watch the introductory video on Rmarkdown to help you build properly the R file.

Moreover, you use GitHub with your team. You'll build a dedicated project for the tasks below and use RStudio with GitHub extensively. You also use Loom to share your findings with other teams in the investment bank.

Learning objectives

Content (scientific rigor, concepts, creativity)

- Choose the right tools.
- Implement the steps correctly.
- Come up with innovative solutions.

Form (coding, collaboration, presentation)

- Build RStudio project with proper folder structure and Rmarkdown/nootebook file to reproduce your results.
- Program with state-of-the-art coding standards.
- Use GitHub repository for collabortive research.
- Use Loom video for presenting your results.

Description

Choose one of the projects below:

Project 1 (Asset management)

The asset allocation team recently launched two long-only risk-based portfolios: 1) minimum-variance portfolio and 2) maximum diversification portfolio. The estimations are all implemented in the package **RiskPortfolios**. Before launching the products, they want to investigate the sensitivity of the portfolios to their inputs: the correlations and the variances. The analysts are interested in the impact on the in-sample and out-of-sample performances.

Your task is to set-up a framework to assess and compare the impact of the parameter uncertainty for the portfolios.

Instructions

Data

1. Consider the first 50 stocks (alphabetical order) in the FTSE 100 universe. Download the data and compute the weekly returns for a period of 4 years.

In-sample sensitivity analysis

1. Display the sensitivity of in-sample reward and in-sample risk of portfolios of size $d = 5, 10, 25$ for the volatility and the correlations. Try to investigate the following questions:
   - Given the covariance structure, what is the impact of the dimension? The choice of stocks (sub-universe)?
   - For a given dimension and correlation structure, what is the impact of the variances?
   - For a given dimension and variances, what is the impact of the correlation? (assume an equi-correlation matrix).

In-sample uncertainty

1. Investigate the impact of parameter uncertainty in the in-sample performance (return and risk, Sharpe). Use first a Gaussian model calibrated on the data.
2. Do the same with a Student model. Calibrate the model on data.
3. Test the impact of robustification techniques. In particular, consider shrinkage approaches.
4. Test the portfolio resampling approach (iid boostrap, block boostrap and Gaussian parametric resampling).

Out-of-sample impact

1. Perform an out-of-sample performance analysis by rebalancing at the weekly frequency. Do this for a selected universe of 25 stocks. Compare the two portfolios.
2. Perform the same analysis using shrinkage approaches. Compare the two portfolios.
3. Perform the same analysis using resampling approaches. Compare the two portfolios.

Out-of-sample with heuristic search

1. Implement an allocation scheme using heuristic search where you invest in 5 to 20 stocks in the universe. Consider two cases:
   - Equally-weighted portfolio.
   - Optimized portfolio.

Project 2 (Risk management)

The objective is to implement (part of) the risk management framework for estimating the risk of a book of European call options by taking into account the risk drivers such as underlying and implied volatility.

Instructions

Data

1. Load the database *Data*. Identify the price of the S&P 500, the VIX index, the term structure of interest rates (current and past), and the traded options (calls and puts).

Pricing of a portfolio of options

1. Assume the following book of European call options: 1x strike $K = 1600$ maturity 20 days, 1x strike $K = 1650$ maturity 20 days, 1x strike $K = 1750$ maturity 40 days and 1x strike $K = 1800$ maturity 40 days.
2. Find the price of this book given the latest underlying price and the latest implied volatility (take the VIX for all options). Use Black-Scholes formula to price the options. Take the current term structure and linearly interpolate to find the corresponding rates. Use 360 days/year for the term structure and 250 days/year for the time to maturity of the options.

One risk driver and Gaussian model

1. Compute the daily log-returns of the underlying stock.
2. Assume they are iid normally distributed.
3. Generate 10 000 scenarios for the one-week ahead (five days) underlying price using the normal distribution fitted to the past invariants.
4. Determine the P&L distribution of the book of options, using the simulated underlying values. Assume the implied volatility stays the same. Take interpolated rates for the term structure.
5. Compute the VaR95 and the ES95.

Note. Do not forget that you are moving forward one week (five days). The maturity of the options and the rate for the term structure are therefore different than for the initial book.

Two risk drivers and Gaussian model

1. Compute the daily log-returns of the underlying stock.
2. Compute the daily log-returns of the VIX.
3. Assume they are invariants normally distributed.
4. Generate 10 000 scenarios for the one-week ahead underlying price and the one week ahead VIX value using the normal distribution fitted to the past risk drivers.
5. Determine the P&L distribution of the book of options, using the simulated values. Take interpolated rates for the term structure.

Two risk drivers and copula-marginal model (Student-t and Gaussian copula)

1. Proceed as before, but assume now that the first invariant is generated using a Student-t distribution with $\nu = 10$ degrees of freedom and the second invariant is generate using a Student-t distribution with $\nu = 5$ degrees of freedom. Assume the normal copula to merge the marginals. Recompute the P&L and the risk figures.

Volatility surface

1. Fit a volatility surface to the implied volatilities observed on the market (traded call and put options). Minimize the absolute distance between the market implied volatilities and the model implied volatilities. The parametric surface is given by:

$$\sigma(m, \tau) = \alpha_1 + \alpha_2(m-1)^2 + \alpha_3(m-1)^3 + \alpha_4\sqrt{\tau}\,,$$

where $m = K/S$ is the moneyness and τ is the time to maturity of the option in years.

2. Re-price the portfolio in one week assuming the same parametric model but shifted by the one-year ATM implied volatility difference.

Note. ATM means at-the-money, which means that $m = 1$. Assume that the one-year ATM implied volatility given by the VIX is $(\alpha_1 + \alpha_4)$.

Full approach

1. Filter the volatility clustering of the log-returns of the underlying using a GARCH(1,1) model with Normal innovations. Use the residuals as invariants.
2. Take and AR(1) model for the log-returns of the VIX. Use the residuals as invariants.
3. Use normal marginals for the invariants and a normal copula.
4. Generate draws for the invariants, compute next week (five days) values and reprice the portfolio.
5. Compute the VaR95 and ES95.