INTEGRATING STATISTICS AND INFORMATION TECHNOLOGY INTO AN INVESTMENT RISK COURSE

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Dated back to the academic year 1990-91, our statistics department has offered the course named "Statistics of Investment Risk," the first investment course in our university. It is rather unusual but we understand that investment risk is making use of many statistical methods. With an explosion in information technology (IT) in the past decade, more IT elements have been integrated into the course so that students can learn through an interactive approach to understand various concepts in modern investment theory. This paper will introduce how to integrate statistics and information technology into an investment risk course.

STATISTICS AND INVESTMENT RISK

In 1990, Professor Harry Markowitz, William Sharpe and Merton Miller won the Nobel Memorial Prize in Economic Science for their great contribution in the field of financial economics. In particular, Professor Markowitz developed the portfolio theory for allocating financial assets optimally and Professor Sharpe developed the CAPM, which forms the foundation of pricing theory for modern financial markets. In the same year, the Department of Statistics and Actuarial Science of the University of Hong Kong has offered the course "Statistics of Investment Risk" as an elective course. Now, it is one of the core courses in our risk management programme. Since 1997, I have been teaching this investment course. The course mainly covers the following topics:

1. portfolio theory
2. asset pricing models
3. market efficiency
4. technical analysis
5. introduction to futures and options

It is well known that most investments involve some risk. The decision to invest or not is usually made against a background of uncertainty. Whilst prediction of the future is difficult, there are statistical modeling techniques which provide a rational framework for investment decisions, particularly those relating to financial markets. Building upon research, both in Hong Kong and abroad, this course presents the prevailing statistical theories for investment decisions in these vital markets. The following lists some investment topics and their related statistical tools.

Investment topics	*Statistical tools*
Portfolio selection	Expected value; variance; covariance; skewness; kurtosis; normal and lognormal distributions; test for normality; robust estimation; Monte Carlo simulation
Capital asset pricing model (CAPM)	Regression analysis
Arbitrage pricing theory	Regression analysis; Factor analysis
Market efficiency	Random walk; runs test; autocorrelation; time series models
Technical analysis	Moving average; control charts
Futures	Regression analysis
Options	Brownian motion; simulation; stochastic calculus

Most of the above topics are covered in the investment course. All students taking this course should have taken the first course in statistics and have a basic knowledge in linear regression analysis. Most of them are second year students from various faculties including science, social sciences, economics and business, etc.

In applying statistical methods to introduce various investment topics, most students found the course interesting but at the same time, they needed to understand a different set of notations. For example, we use the symbols x or y to represent a random variable but in this course, we often use the symbols r and R to represent a rate of return on an asset which is of course a random variable. A typical regression model $y = a + bx + e$ in our context will be written as $R = a + b\,Rm + e$, where R and Rm are returns on a risky asset and the market index.

When I first taught this course, there were not many investment textbooks with a sufficient introduction to the statistical tools. The one I used is by Elton, Gruber, Brown and Goetzmann (2003) and its older versions. This book gives a detailed derivation on portfolio analysis. However, the notations used in the book are not so proper in a statistical sense. For instance, the book used $\overline{R}$ instead of E(R) to represent the expected return of an asset. It would be easy to get confused, particularly for our statistics major students. Now, I am using the book *Statistics and Finance: An Introduction* written by an engineering professor, Ruppert (2004). This book is a good mix of statistical and financial topics.

INFORMATION TECHNOLOGY AND INVESTMENT RISK

In the past decade, there were rapid developments in computer and data storage technologies. More and more online financial databases and electronic trading business have evolved. In order to help the students to learn the theories and the methods through analyzing real data such as the stock price data in Hong Kong, a popular electronic spreadsheet, *EXCEL*, was first used in the course in 1999. However, because of the diverse mathematical background and computer knowledge of the students, some students found it difficult in using *EXCEL* to write mathematical formulae such as matrix operations.

Starting from 2001, I thus shifted to use "The Investment Portfolio," a portfolio management software accompanying the textbook written by Elton *et al*. (2003). Although the software provides an easy-to-use window interface for creating, evaluating and managing portfolios, students' feedbacks collected in 2001 and 2002 indicated that the software could not read stock price data with more than 3 decimal places (this is often not enough for storing daily stock return data) and it sometimes automatically exited possibly due to system errors. This definitely discourages students learning and, more importantly, it may provide inaccurate answers.

In order to tackle the above problem, I was awarded a teaching development grant in 2003 for developing a Java software named *jPORT-imizer* (i.e., Java Portfolio optimizer) to facilitate the construction of an optimal portfolio of stocks based on the mean-variance optimization technique. The following lists the main features developed in this software:

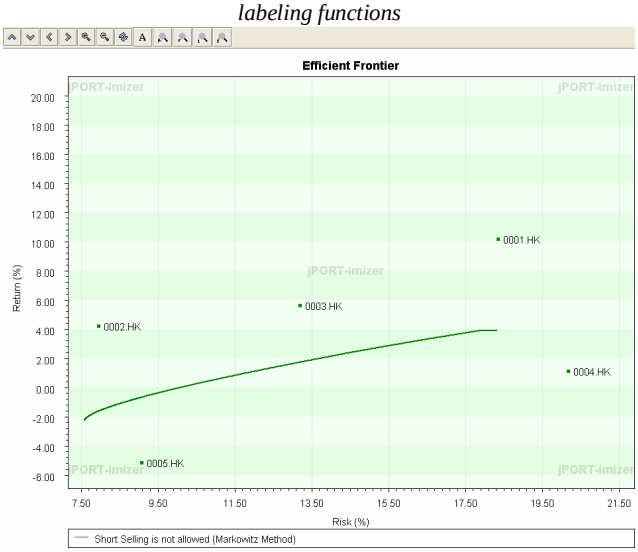
- Download raw data from free online database Yahoo@Finance.
- Estimate the expected return, risk and beta coefficients
- Draw efficient frontier with short-selling allowed or not allowed
- Allow to input summary statistics for portfolio construction
- Allow different currencies for different assets
- Provide a Monte Carlo simulation tool for constructing the efficient frontier
- Provide a robust method of estimating expected return and covariance matrix of the assets
- Provide three methods of estimating the value-at-risk of a stock portfolio, namely historical simulation, Monte Carlo simulation and the methods based on one of the three financial time series models, namely, RiskMetrics model, orthogonal EWMA and orthogonal GARCH models

A webpage has been designed to store all the detailed description of the learning toolbox, case studies and links to financial data sources. I have designed some questions in each assignment to ask students to use the software to construct optimal portfolio such as the tracking fund of Hang Seng Index. Students in the course evaluation found the software easy to use and it helped them to understand the theory and gain hands on experience in building their own portfolio by analyzing real financial data.

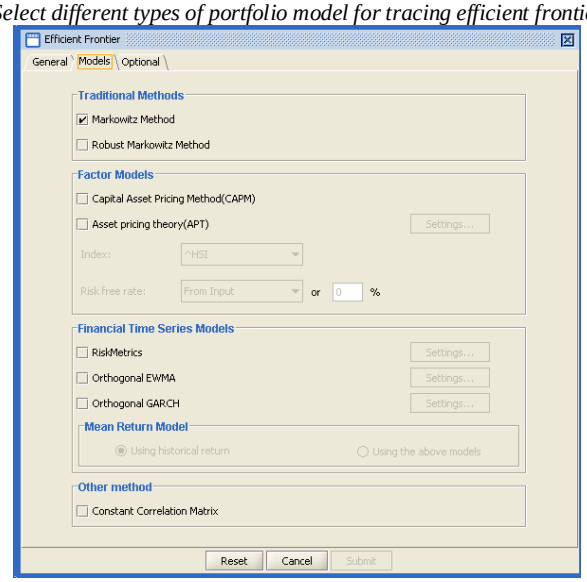
In developing the learning toolbox, we found that the accuracy of the input parameters is very important in constructing a good portfolio. As the input parameters are often estimated based on historical data, we suggest using a robust method to estimate these input parameters. Together with the Monte Carlo method, this leads to a new portfolio construction method which has not been developed in the literature. Empirical studies found that the robust Monte Carlo method often beats the classical Markowitz method.

This learning toolbox, which contains new advances in research, undoubtedly provides more portfolio construction and risk management methods that will strengthen our teaching. Students can learn through an interactive approach so that they can study the performance of various portfolio construction methods and risk management methods. Without this toolbox, this is definitely very difficult.

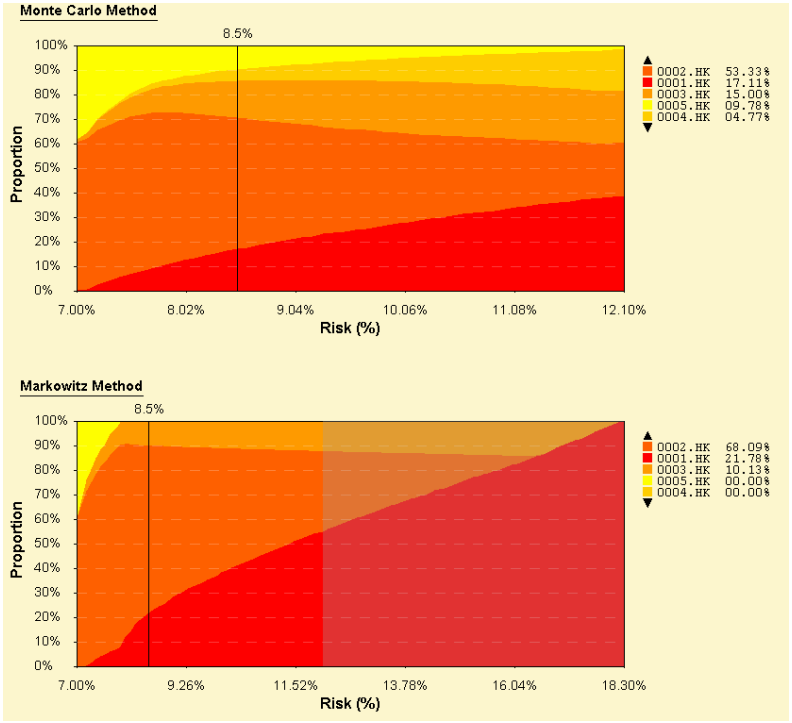
Efficient frontier graph with navigation, zooming, searching and labeling functions



Select different types of portfolio model for tracing efficient frontier



Using this toolbox, an instructor can have a live demonstration to explain various concepts in modern portfolio theory and financial engineering. For instance, we can demonstrate the need for robust estimation of input parameters and the need for the Monte Carlo method in portfolio construction. It is sensible to see from the following figure that the portfolio weightings constructed by Monte Carlo method change smoothly and slowly when the portfolio risk increases and no stock is suddenly added to or dropped from the portfolio.



Here is another example. In one of the assignments, students were first asked to derive the method of constructing a tracking fund of Hang Seng Index and then collect their own choice of stocks to build the fund using *jPORTimizer*. Students found that they could put the theory into practice and also realized some other practical problems such as the selection of stocks and the number of stocks to be used.

CONCLUSIONS

With the availability of the learning toolbox, we can provide a problem-based learning environment for students to learn not only the statistical and financial theories but also to gain the practical experience of applying the theories to solve real problems.

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