PORTFOLIO PERFORMANCE INCORPORATING THREE FACTORS MODEL : THE RESAMPLE PORTFOLIO APPROACH

KANIS CHARNTAWEEKHUN

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........KANIS CHARNTAWEEKHUN........
Mr. Kanis Charntaweekhun
Candidate

....
Asst. Prof. Sarayut Nathaphan, D.B.A.
Major advisor

....
Miss Ornlatcha Sivarak, Ph.D.
Co- advisor

....
Prof. Banchong Mahaisavariya,
M.D., Dip Thai Board of Orthopedics
Dean Faculty of Graduate Studies
Mahidol University

....
Asst. Prof. Yingyot Chiaravutthi, Ph.D
Program Director
Master of Business Administration
Program in Business Modeling and Analysis
International College
Mahidol University

Thesis
entitled

PORTFOLIO PERFORMANCE INCORPORATING THREE FACTORS MODEL : THE RESAMPLE PORTFOLIO APPROACH

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on
September 5, 2010

KANIS CHARNTAWEEKHUN
Mr. Kanis Charntaweekhun
Candidate

Asst. Prof. Sorasart Sukcharoensin, D.B.A.
Chair

Miss Ornlatcha Sivarak, Ph.D.
Member

Asst. Prof. Sarayut Nathaphan, D.B.A.
Member

Prof. Banchong Mahaisavariya,
M.D., Dip Thai Board of Orthopedics
Dean Faculty of Graduate Studies
Mahidol University

Assoc. Prof. Rassamidara Hoonsawat,Ph.D.
Dean
International College,Mahidol University

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Kanis Charntaweekhun

PORTFOLIO PERFORMANCE INCORPORATING THREE FACTORS MODEL : THE RESAMPLE PORTFOLIO APPROACH

KANIS CHARNTAWEEKHUN 5038656 ICMA / M

M.B.A. (BUSINESS MODELING AND ANALYSIS)

THESIS ADVISORY COMMITTEE : SORASART SUKCHAROENSIN, D.B.A., SARAYUT NATHAPHAN, D.B.A., ORNLATCHA SIVARAK, Ph.D.

ABSTRACT

This thesis compares the performance of three optimal portfolios formed by Traditional Mean-Variance, the Capital Asset Pricing Model, and the Fama-French three-factors Model (FF3F) with different numbers of historical observations based on equities listed on emerging stock exchanges. The common portfolio performance measurements were the Treynor and Sharpe ratios. However, comparing portfolio performance across different methods based on the Treynor ratio was not an easy task. Since portfolio beta is one of the key parameters in the Treynor ratio, the ratio thus cannot be calculated for portfolios constructed by the Fama-French Three-factor Model. This thesis proposed a solution to find an adjusted Treynor Ratio for all portfolios. Additionally, a supercomputer or grid-computing is normally required to construct a portfolio from a large number of assets. This prevents retail investors from applying the modern portfolio theory to their investment strategy. This thesis employed a technique called the Portfolio Re-Sampling Approach (PRESA) to enable an 800 MHz computer to construct optimal portfolios from a large set of assets. An optimal portfolio constructed by using the Fama-French three factors model with 3 years historical data was the best performing portfolio in this research.

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KEY WORDS: FF3F / Optimal Portfolio / PRESA / CAPM / Portfolio Measurement

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ผลตอบแทนจากพอร์ทการลงทุนตามแบบจำลอง THREE FACTORS MODEL : การวิเคราะห์ปัจจัยโดยการสุ่มตัวอย่างในพอร์ทการลงทุน

PORTFOLIO PERFORMANCE INCORPORATING THREE FACTORS MODEL : THE RESAMPLE PORTFOLIO APPROACH

คณิศร์ ชาญทวีคุณ 5038656 ICMA / M

บธ.ม. (การวิเคราะห์และการสร้างตัวแบบธุรกิจ)

คณะกรรมการที่ปรึกษาวิทยานิพนธ์ : สรศาสตร์ สุขเจริญสิน, D.B.A., สรายุทธ์ นาทะพันธ์, D.B.A., อรลัชชา ศิวรักษ์, Ph.D.

บทคัดย่อ

งานวิจัยนี้เป็นการเปรียบเทียบประสิทธิภาพของตัวแบบการสร้างพอร์ทโฟลิโอแบบที่มีศักยภาพสูงที่สุดจากวิธีต่างๆ 3 วิธี ได้แก่ Traditional Mean-Variance, Capital Asset Pricing Model และ Fama-French Three-factor Model โดยใช้ข้อมูลในอดีตของหุ้นใน Emgering Market อัตราส่วนหลักที่ใช้ในการเปรียบเทียบประสิทธิภาพของพอร์ทโฟลิโอได้แก่ อัตราส่วนTreynor และอัตราส่วน Sharpe อย่างไรก็ตามในการคำนวณหาอัตราส่วน Treynor นั้นจำต้องระบุค่า beta ของพอร์ทโฟลิโอซึ่งทำให้ ฟอร์ทโฟลิโอที่มีศักยภาพสูงที่สุดที่สร้างโดยใช้วิธีของ Traditional Mean-Variance และ Fama-French Three-factor Model ไม่สามารถหาอัตราส่วน Treynor ได้ เนื่องจากพอร์ทโฟลิโอที่มีศักยภาพสูงที่สุดที่สร้างโดยใช้วิธี Fama-French Three-factor Model มีค่า beta จำนวน 3 ค่า และ วิธี Traditional Mean-Variance ไม่มีค่า beta ของพอร์ทโฟลิโอ วิธีการแก้ปัญหาในประเด็นนี้เป็นส่วนหนึ่งในงานวิจัยฉบับนี้ นอกจากนั้นงานวิจัยฉบับนี้ยังได้นำเสนอวิธีการที่ทำให้เครื่องคอมพิวเตอร์ระดับที่ใช้งานตามบ้านสามารถใช้การเขียนโปรแกรมเชิงเส้นเพื่อหาฟอร์ทโฟลิโอที่มีศักยภาพสูงที่สุดจากหุ้นจำนวนมากๆได้โดยใช้วิธีที่ชื่อว่า Portfolio Re-Sampling Approach (PRESA) ผลจากการวิจัยครั้งนี้พบว่าพอร์ทโฟลิโอที่สร้างด้วยวิธี Fama-French Three factors Model โดยใช้ข้อมูลในอดีตจำนวน 3 ปีมีประสิทธิภาพสูงที่สุด

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CHAPTER I
INTRODUCTION

Although many asset pricing models, such as CAPM, Traditional Mean, and the Fama-French three factors model, are taught in academic institutions, investors rarely apply them in practicality. The complexity of the models makes them unattractive. For instance, the expected return estimation using the Fama-French three factors model requires 3 estimations of complex parameters, which are market beta, small minus big beta, and high book-to-market ratio minus low book-to-market ratio beta. The reasons are not only the complexity of calculation and data collection but also investor uncertainty over which model is appropriate for the market. Additionally, the length of historical data set does not have a constant number of observations for calculating the expected return with any model.

This chapter presents an overview of the thesis, a statement of problems, the study objective, an assumption, and the scope of the study.

1.1 Overview

Most of the time, the inflation rate is a positive number, which means the value of money decreases every year. In 1970, an ounce of gold was worth less than $50 per ounce, but its value rose to over $1250 in 2010. The way to avoid depreciation in money is to invest one's wealth at a higher rate of return than the inflation rate. However, the expected rate of return or required rate of return of each individual tends to be higher than the inflation rate.

Investing in low risk assets is common for risk-adverse people. Government bonds, Treasury bills, saving deposits, and corporate bonds are examples of investments in money markets. In spite of investing in money markets being a low risk investment, it generates a lower return compared with other choices of investment.

Many people put their money in property investment with the perspective that the value of land never drops. However, liquidity is the drawback of this type of investment.

Another choice of investment is the equity market. Return in an equity market can be grouped into 2 types, which are capital gain and dividend yield. Dividend yield depends on the numbers in the financial statement, but capital gain is related to a future viewpoint of the company.

The fair value of stock is the common question from amateurs and some professional investors. Numbers in a financial report are the basic information to measure the fair value of stock, but they are not real-time updated. Technical style is one of the methods to estimate the fair value at a particular point of time. It is transforming a movement in price to be a psychology analysis. Since it is analysis based on analyst opinions, sometimes it can make a profit but sometimes negative return is generated. Asset pricing models are the reasonable method of estimating the expected value. They can be calculated real-time and analyzed based on the real information.

The stock with the highest return is not always the best stock in the market if it has high risk. Stock price is not only affected by the company's situation, but also influenced by the economic situation in the same direction. Thus, types of risk incorporated with the equity market can be categorized into 2 groups, which are systematic and firm-specific risk. Systematic risk is the risk of the market, so investors cannot eliminate a systematic risk. Another type of risk, firm-specific risk, can be reduced by forming an optimal portfolio.

The process of forming a portfolio is divided into 2 steps. The first step is evaluating the characteristics of securities, and the second is finding the optimal portion of each security in order to generate the highest return on the given level of risk or lowest level of risk on the given return.

There are many combinations of stock in a portfolio selection process. The common quantitative method to measure portfolio performance is the Sharpe Ratio and Treynor Ratio. The portfolio with the higher ratio is the better portfolio.

There are many asset pricing models, so the first question is: which model is the best model? This thesis compares the performance of 3 optimal portfolios formed by Traditional Mean-Variance, the Capital Asset Pricing Model and the Fama French 3 Factors Model based on equities listed on stock exchanges in emerging markets. In terms of the estimation on historical data, the second question is: how long should the estimated value calculation be? Unfortunately, portfolio beta is one of three parameters in the Treynor Ratio. As a result, the Treynor Ratio cannot be calculated for portfolios constructed by the Fama French 3 Factors Model because the Fama French 3 Factors Model generates 3 betas for 1 asset. This thesis proposes 2 solutions to find an adjusted Treynor Ratio for portfolios generated from the Fama French 3 Factors Model.

A supercomputer, grid-computing or high performance computer is required to construct a portfolio from a large number of assets. This is the limitation for retail investors to apply modern portfolio theories to the real world. This paper introduces a portfolio re-sampling approach (PRESA) to enable a 1 GHz computer with 2GB of RAM to construct an optimal portfolio from a large set of assets.

1.2 Statement of Problem

Many retail investors may invest in a stock market without applying financial knowledge. They usually follow their instinct when moving money in the stock market. There are many limitations for retail investors to utilize financial theory in a stock market.

Level of difficulty and an unclear framework are some limitations in terms of educational background. Even though there are many asset pricing models, they may not know which model is the most appropriate for a certain market. The number of historical observations for forming asset parameters has not been identified. Both the asset pricing model and the number of historical observations must be identified in the first step of portfolio optimization.

The reason is not only the level of difficulty but also the capacity of technology. An optimal portfolio construction process requires a high performance computer. Moreover, an optimal portfolio selection covering a large number of assets might require grid computing technology, which is extremely expensive. That is a limitation of applying financial theory in terms of technology.

1.3 Objective

During 2009, emerging markets were significantly outstanding among all the world's stock markets. Thus, this research will apply portfolio optimization to emerging markets with 3 models that are traditional mean variance, CAPM, and the Fama-French three factors mode. The level of difficulty is harder than the optimization for only one country because emerging markets contain more than 10,000 assets. Optimization with a large number of assets requires a supercomputer or grid-computing, which is extremely expensive. In order to enable a normal computer set to calculate the optimal portfolio for a large number of assets, this research introduces a new method in the portfolio optimization process. The new method is called the portfolio re-sampling approach (PRESA). Since PRESA is the new method in portfolio optimization, this research will conduct a PRESA validation test to prove that this method is reliable.

After the portfolio construction process, all portfolios will be benchmarked with the Sharpe ratio and Treynor Ratio with portfolio return in the next period. Estimating the Treynor Ratio for portfolios created with traditional mean variance, the Fama-French three factors model, and the naïve portfolio is impossible because a single portfolio beta is required to calculate the Treynor ratio. Only portfolios constructed by CAPM can calculate the Treynor ratio. This research will propose a single portfolio beta estimation for general portfolios in order to calculate the Treynor ratio for all portfolios.

1.4 Assumption

The PRESA technique can be applied for any group of assets regardless of the number of stocks. Optimal portfolio models can be applied for a group of assets from many countries, such as emerging markets with a normal computer set by using the portfolio re-sampling approach. After the portfolio selection process, the Treynor ratio can be calculated for all portfolios by using the methods proposed in this research.

The traditional mean variance model directly uses historical information as its parameter, so the future portfolio performance should not be higher than the CAPM and Fama-French three factors models. The Fama-French three factors model calculates the expected return by considering the market return, market capital parameter, and book-to-market variable; meanwhile, CAPM considers only the correlation between stock return and market return. Thus, the last assumption is that the Fama-French three factors model with 3 year historical observations delivers the best performance portfolio in emerging markets.

1.5 Scope of Study

This thesis focuses on optimal portfolio construction and measurement by using a new computing algorithm for the Markowitz optimal portfolio model, CAPM, Fama-French three factors model, and naïve portfolio model in emerging markets, including Argentina, Brazil, Chile, China, Colombia, India, Indonesia, Israel, Malaysia, Mexico, Pakistan, Peru, Philippines, Russia, South Africa, Sri Lanka, Taiwan, Thailand, Turkey, and Venezuela. All calculations will be made with Matlab 2008a on a 1 GHz computer with 2GB of RAM.

CHAPTER II
LITERATURE REVIEW

This research will start with return estimation using traditional mean, CAPM, and the Fama-French three factors model before using linear programming to construct portfolios with parameters calculated from those models. The last step is to calculate the Sharpe Ratio and Treynor Ratio to benchmark optimal portfolios from 4 models, namely traditional mean variance, CAPM, Fama-French three factors model, and naïve portfolio.

There are 2 main parts to the literature review, which are financial literature review and linear programming related to financial research. The financial literature review covers capital asset pricing models, optimal portfolio construction, and portfolio performance measurement.

2.1 Financial Literature Review

Harry Markowitz (1952) originated the first efficient portfolio model that either produces a portfolio with the highest expected return given a level of risk or produces a portfolio with the lowest risk given a particular expected return. He suggests that portfolio selection on expected return is not adequate. He considers the expected return – variance of return (E-V) rule instead. Thus 2 properties - expected return and variance of return - must be evaluated by the following equations:

$$E(r_p) = \sum r_i x_i \quad (1)$$

$$\sigma_{ij} = E\{[r_i - E(r_i)][r_j - E(r_j)]\} \quad (2)$$

$$V = \sum_{i=1}^{N} \sum_{j=1}^{N} \sigma_{ij} r_i r_j \quad (3)$$

Where

r_i = Historical return on asset i

r_j = Historical return on asset j

x_i = Percentage of asset i in portfolio

There are 2 drawbacks of the Markowitz efficient portfolio. The first is Markowitz used historical information to represent future portfolio return. The second is the large number of estimates. For example, to construct an efficient frontier of 10,000 stocks, Markowitz needed to estimate 10,000 values of expected return, and 100,000,000 values of covariance between return on each asset. As a result, forming an efficient portfolio using the Markowitz method requires 100 million estimated values.

Portfolio selection became more practical after Sharpe (1964), Linter (1965) and Mossin (1966) proposed the Capital Asset Pricing Model (CAPM) which is a linear relationship between expected individual asset return and market risk premium assuming perfect market conditions. CAPM can be represented by Equation (4). Since the risk free rate and market risk premium are equal in the same market, only market beta affects the expected security return with any positive correlation. Security with high beta, β, has high volatility relative to the low beta asset. The uncertainty level of individual assets can be captured by beta. Beta of asset i, β_i, is calculated from the covariance between the return on security i and the market return divided by the variance of market return as shown in Equation (5).

$$E(r_i) = r_f + [E(r_M) - r_f]\beta_i + \varepsilon, i = 1,..., N \qquad (4)$$

Where

r_f = Risk free rate of return

$E(r_M)$ = Expected return on market portfolio

β_i = Beta coefficient

$$\beta_i = \frac{\text{cov}(r_i, r_M)}{\sigma^2(r_M)} \qquad (5)$$

Where

r_i = Return on security

r_M = Return on market portfolio

Measuring risk on individual security is more convenient with CAPM, so it is used widely in the academic and financial industry. Fama and Macbeth (1973) validated whether CAPM satisfied 3 conditions: the function between stock return and market function is linear, beta is the only factor that makes the expected return of all stocks different, and beta is a positive value. The expected return generated form CAPM worked properly in the 1970s. On the other hands, Douglas (1969) suggested that it was not only beta that affects the expected return, but other factors, which were unknown at that time, also have significant power. Chen, Roll and Ross (1986) developed a model incorporating economic factors, industrial production (IP), risk premium on corporate bonds (CG) and unanticipated inflation (UI), with stock return as shown in Equation (6).

$$E(r) = a + \beta_{IP} IP + \beta_{UI} UI + \beta_{CG} CG + \varepsilon \qquad (6)$$

Where

a = constant

IP = monthly growth rate in industrial production

UI = Unanticipated inflation

CG = Unanticipated change in risk premium (long-term government bond return – bond return)

Banz (1981) discovered another factor, which is the size of market equity, ME, that impacts the expected return on stock. He found a negative relation between ME and expected return. Basu (1983) found that the E/P ratio had a power to estimate the expected return. A security with high E/P tends to have a higher return relative to a security with a low E/P ratio. Leverage was a major key factor founded by Bhandari (1988). A stock with a high debt to market equity ratio tends to have higher expected return than ones with a low ratio. Statman (1980) and Rosenberg, Reid and Lanstein (1985) studied the effect of a book to market ratio, BE/ME, on the expected return. Higher expected return was the property of stock with the high book to market ratio. Fama and French (1992) introduced the Fama French 3 Factors Model as shown in Equation (7). They suggested that the expected stock return could be explained by market return, market equity and book to market ratio. They categorized all securities into 3 groups - small (S), medium (M) and big (B) - by market equity and also allocated all security into 3 groups by book to market ratio. The first 30 percent of ranked securities is named the low book to market equity group (L). The next 40 percent is called the medium book to market equity group (M), and the rest is the high book to market group (H). S/H is the portfolio containing securities in the small market equity and high book to market group. S/M is the portfolio containing securities in the small market equity and medium book to market group. S/L is the portfolio containing securities in the small market equity and low book to market group. B/H is the portfolio containing securities in the big market equity and high book to market group. B/M is the portfolio containing securities in the big market equity and medium book to market group. B/L is the portfolio containing securities in the big market equity and low book to market group. SMB is an average difference between return on the small market equity group (average return of return on S/H, S/M and S/L), and the big market equity group (average return of return on B/H, B/M and B/L). HML represents an average difference between return on the high book to market group (average return of return on S/H, M/H and B/ H) and low book to market group (average return of return on S/L, M/L and B/ L).

$$r_{it} - r_{ft} = \alpha_i + \beta_{iM}(r_{Mt} - r_{ft}) + \beta_{is} SMB_t + \beta_{ih} HML_t + \varepsilon_{it} \quad (7)$$

Where

r_{it} = return on security i at period t

r_{ft} = risk free rate at period t

r_{Mt} = return on market portfolio at period t

SMB_t = average different between return on small market equity group and big market equity group at period t

HML_t = average different between return on high book to market group and low book to market group at period t

Blume (1970) improved the precision of the beta coefficient from CAPM by working with portfolios. x_i is the percentage of security i's market value. The market value can be calculated by multiplying the number of shares in the portfolio with the stock price The value of x_i is always positive because it is not allowed to short sell on any securities. The summation of x_i is equal to 1. Risk of portfolio can be calculated with weighted average on β_i.

$$E(R_p) = \sum_{i=1}^{N} x_i r_i \quad (8)$$

$$E(\beta_p) = \sum_{i=1}^{N} x_i \beta_i \quad (9)$$

$$\sum_{i=1}^{N} x_i = 1 \quad (10)$$

Since there are many methodologies to construct portfolios, portfolio performance measurement is an interesting issue. There are several approaches to evaluate the performance of mutual fund managers. Sharpe (1966) originated the reward-to-variability ratio, known as the Sharpe ratio, to benchmark the performance of portfolios. This ratio can be calculated as in Equation (11). The portfolio with the highest Sharpe ratio indicates the best portfolio. Treynor (1966) created a ratio which was similar to the Sharpe ratio but his ratio used systematic risk instead of total risk as shown in Equation (12)

$$S = \frac{E(r_P) - r_f}{\sigma_A} \quad (11)$$

$$T = \frac{E(r_P) - r_f}{\beta_P} \quad (12)$$

In practical terms, the Sharpe ratio may not be suitable when comparing portfolios with different levels of risk. Modigliani (1997) used M^2 to measure the performance of fund managers. M^2 is similar to the Sharpe ratio but the variance of the portfolio is adjusted to be the same level of variance as the market portfolio. Thus, the difference of M^2 between the 2 portfolios is an excess return between those portfolios given the same level of risk. The method to reduce the variance of the portfolio is to set the ratio of investment in money markets to a risky portfolio, and then calculate M^2 as in Equation (13).

$$M^2 = r_{P*} - r_M \qquad (13)$$

Where r_{P*} = adjusted return on portfolio

2.2 Linear Programming Literature Review

One of the most efficient methods to optimize the process is Linear Programming (LP). Linear Programming is a mathematical method to find the best outcome with the set of conditions. There are 3 main components in the Linear Programming model: decision variables, objective function, and constrains.

Decision variables are sets of inputs, which can be adjusted or controlled in the process. Objective function is a linear function of output and input. Constrains are a limitation of input.

The Markowitz optimal portfolio can be constructed by using Linear programming as in the following model:

Portfolio return at time t is :

$$r_p(t) = \sum r_i(t) x_i \qquad (14)$$

Portfolio risk is :

$$risk(x) = \frac{1}{T} \sum_{t=1}^{T} \left| \sum_{i=1}^{N} r_i(t) x_i - \frac{1}{T} \sum_{t=1}^{N} \sum_{i=1}^{N} r_i(t) x_i \right| \qquad (15)$$

Linear Programming model for Markowitz optimal portfolio is

Decision Variable = the fractions x_i

Objective = maximize return (Equation 14 and 15)

Constrain = Equation 16, 17, and 18

$$\frac{1}{T}\sum_{t=1}^{T}\left|\sum_{i=1}^{N} r_i(t)x_i - \frac{1}{T}\sum_{t=1}^{N}\sum_{i=1}^{N} r_i(t)x_i\right| \le RiskAversionLevel \tag{16}$$

$$\sum_{i=1}^{N} x_i = 1 \tag{17}$$

$$x_i \ge 0 \tag{18}$$

CHAPTER III
METHODOLOGY

To prove the assumptions stated in chapter 1, there are 4 major activities: data collection, measurement of each security's properties, portfolio selection and out of sample portfolio performance measurement.

The monthly index returns of all securities listed in emerging markets during the period December 1997 to December 2008 were downloaded from DataStream. The emerging market index represents market returns.

The return of all securities are assessed with 3 models: Traditional Mean-Variance (Markowitz Method), CAPM and FF 3 Factors Model. Then the portfolio re-sampling approach (PRESA) technique is used to construct optimal portfolios. This research also compares the performance of optimal portfolios constructed from 2 timeframes of historical data which are 5 years of historical data and 3 years of historical data. The rolling window technique with 3 years and 5 year cycles will be applied every 12 months..

The percentage of asset allocation from each optimal portfolio will be constant and use out of sample data, which is a return on asset after a portfolio construction period, to calculate out of sample portfolio performance. This paper will compare out of sample portfolio performance constructed by using 3 methods. All tests will be conducted with a low-end computer set.

3.1 Equipments and Programs

A 800Mhz 32Bit computer set with 2 GB of RAM is the computer used in all tests to verify that a low performance computer set can create optimal portfolios for a large number of assets by using the portfolio re-sampling approach (PRESA) technique. MATLAB version 7.6.0 (R2008a) for Microsoft Windows 32 Bits is the main data analysis tool for processing raw data from databases and executing the tests. Minitab version 15 is used for summarized test results in a statistical perspective.

3.2 Data Collection

The emerging markets include Argentina, Brazil, Chile, China, Colombia, India, Indonesia, Israel, Malaysia, Mexico, Pakistan, Peru, Philippines, Russia, South Africa, Sri-Lanka, Taiwan, Thailand, Turkey, and Venezuela.

There are 8,966 assets' of monthly information extracted from DataStream (Thomson Database). There are 4 data sets for each company's information, which are stock price in a local currency, stock price in US cents, market value of the company, and market to book ratio. Price in a local currency is used to determine the movement of stock value. Price in US cents is used as standard price for this research since many currencies are included in this research. Market value and market to book ratio are required for the Fama-French 3 Factor Model.

Data validation begins with screening out incomplete data. Securities which are missing a price in the local currency, price in US cents, market value, or market to book ratio will be out of scope in this research. The second stage is identifying the valid period of each stock. An invalid period is defined by delisted date or stock with static local currency price for 3 consecutive months. The next step is selecting only primary stock data, which does not include B-Share in China or FB in Thailand, for example.

12 sets of historical data as shown in Table1 will be used to construct an optimal portfolio for each of the sample portfolios. For example, the sample portfolios for 2005 are constructed by using data from Dec 2001 - Dec 2004 and Dec 1999 - Dec 2004.

Table3.1 Period of historical data by out of sample portfolio and window size

Out of sample	3 Years Historical Optimal Portfolio	5 Years Historical Optimal Portfolio
2003	Dec 1999 – Dec 2002	Dec 1997 - Dec 2002
2004	Dec 2000 – Dec 2003	Dec 1998 - Dec 2003
2005	Dec 2001 – Dec 2004	Dec 1999 - Dec 2004
2006	Dec 2002 – Dec 2005	Dec 2000 - Dec 2005
2007	Dec 2003 – Dec 2006	Dec 2001 - Dec 2006
2008	Dec 2004 – Dec 2007	Dec 2002 - Dec 2007

3.3 Expected Return on Assets

Two asset pricing models, namely CAPM and the Fama-French 3 Factors Model, and an average of historical data are used in this thesis to calculate expected returns on assets.

CAPM Beta is calculated by using regression between stock monthly excess return and market risk premium. After all betas are calculated for all stocks, market risk premium is substituted in the model to estimate expected returns.

SMB and HML are required for the Fama-French 3 Factors Model. Two additional properties, namely size and book to market ratio, are assigned to every stock. There are 2 levels for size property, which are big and small. The size threshold is the 50th percentile of market value. Value of a book to market property can be high, medium, or low. The first 30% of ascending sorted book to market is the low group. The last 30% of a sorted ratio is the high group, and the rest is the medium group. SMB is calculated by the naïve portfolio of the small size group minus the naïve portfolio of the big size group. HML is calculated by the naïve portfolio of the high book to market ratio group minus the naïve portfolio of the low book to market ratio group. Fama-French 3 Factors Betas are calculated with multiple regressions between stock excess return and 3 market values, which are market risk premium, SMB, and HML. Then the 3 market values are put into the model to find the expected return.

3.4 Portfolio Re-Sampling Approach (PRESA) technique

When investors utilize low-end computers to construct an optimal portfolio with a certain number of assets by using the ordinary linear programming method, they will be obstructed by computer performance limitations; for example, the memory is not enough. The portfolio re-sampling approach (PRESA) technique will be the method to overcome the memory and processor performance limitations. The process of portfolio re-sampling approach consists of 6 steps:

1. Randomize the position of assets
2. Select the first sampling group with any number of stock
3. Construct the optimal portfolio by using linear programming for sampling group in step 1
4. Filter out stocks with zero asset allocation in step 2
5. Combine the remaining stocks with the new sampling group with any number of stock
6. Repeat step 3 – 5 until all assets are involved in the process

Iteration or recursive procedures can be used to implement this technique. Even though a recursive procedure is appropriate for this algorithm, the limitation of a number of nested iterations for a recursive procedure in MATLAB forces the iteration technique to be used in this research. Details of PRESA will be discussed at length in chapter 4.

3.5 Optimal Portfolio Formation using Markowitz Method

The stock return of each firm is calculated by using a mean of historical data. The variance-covariance Matrix is constructed by using the traditional statistics method. After the mean of a historical return and covariance matrix are calculated, the portfolio re-sampling approach (PRESA) technique is used for finding the efficient frontier and optimal weight of asset on every level of portfolio risk. Portfolio risk and return are calculated from optimal weight.

3.6 Optimal Portfolio Formation using CAPM

Stock beta in each period is calculated by using regression between stock return, as shown in equation (4) , and market return. The covariance matrix is constructed on the assumption that every stock is independent of each other. Thus the covariance matrix is created by using equation (14).

$$Var_a = E\left(\left(r_{rf} + \beta_a r_m - \beta_a E(r_m) - \varepsilon\right)\left(r_{rf} + \beta_a r_m - \beta_a E(r_m) - \varepsilon\right)\right)$$

$$Var_a = E\left(\left(\beta_a(r_m - E(r_m)) - \varepsilon\right)\left(\beta_a(r_m - E(r_m)) - \varepsilon\right)\right)$$

$$Var_a = E\left(\beta_a^2(r_m - E(r_m))^2 - 2\,\beta_a(r_m - E(r_m))\varepsilon + \varepsilon^2\right)$$

$$Var_a = \beta_a^2\sigma_m^2 + \sigma_\varepsilon^2 \qquad (14)$$

Linear programming is utilized to draw the efficient frontier and optimal weight of asset for each level of portfolio risk.

3.7 Optimal Portfolio Formation using Fama French 3 Factors Model (FF3M)

There are 3 parameters that are the same in the market. They are market return, SMB, and HML. Those parameters are changed over time. SMB is the difference between the return of small firms' portfolios and the return of big firms' portfolios. HML is calculated from the return of all stock in the high book to market ratio group minus the return of all stock in the low book to market firms. Size threshold is defined with the mid point of sorted market value. For HML, there are 2 threshold points. The first threshold is the 30 percentile of a sorted book to market value and the second threshold is the 70 percentile of a sorted book to market value. The high book to market ratio group consists of the firms with a book to market ratio above the second threshold. The low book to market ratio group is stocks with a book to market ratio less than the first threshold. The return of each group is calculated from an equal weighted method.

The coefficient set of each firm is calculated with equation (7). Then, the expected return is generated from 3 parameters with the firm's coefficient set. The variance-covariance matrix is constructed by using equation (15). Optimal weight of each stock and efficient frontier are created by using linear programming.

$$Cov_{a,b} = E\left[\beta_{Ma}(MRP - E(MRP)) + \beta_{Sa}(SMB - E(SMB)) + \beta_{Ha}\left(HML - E(HML) + \varepsilon_a\right)\right]\left[\beta_{Mb}(MRP - E(MRP)) + \beta_{Sb}(SMB - E(SMB)) + \beta_{Hb}\left(HML - E(HML) + \varepsilon_b\right)\right]$$

$$Cov_{a,b} = E\left[\beta_{Ma}\beta_{Mb}(MRP - E(MRP))^2 + \beta_{Ma}\beta_{Sb}(MRP - E(MRP))(SMB - E(SMB)) + \beta_{Ma}\beta_{Hb}(MRP - E(M))(HML - E(HML)) + \beta_{Ma}(MRP - E(MRP))\left(\varepsilon_b - 0\right) + \beta_{Sa}\beta_{Mb}(SMB - E(SMB))(MRP - E(MRP)) + \beta_{Sa}\beta_{Sb}(SMB - E(SMB))^2 + \beta_{Sa}\beta_{Hb}(SMB - E(SMB))(HML - E(HML)) + \beta_{Sa}(SMB - E(SMB))\left(\varepsilon_b - 0\right) + \beta_{Ha}\beta_{Mb}(HML - E(HML))(MRP - E(MRP)) + \beta_{Ha}\beta_{Sb}(HML - E(HML))(SMB - E(SMB)) + \beta_{Ha}\beta_{Hb}(HML - E(HML))^2 + \beta_{Ha}(HML - E(HML))\left(\varepsilon_b - 0\right) + \beta_{Mb}(MRP - E(MRP))\left(\varepsilon_a - 0\right) + \beta_{Sb}(SMB - E(SMB))\left(\varepsilon_a - 0\right) + \beta_{Hb}(HML - E(HML))\left(\varepsilon_a - 0\right) + \left(\varepsilon_a - 0\right)\left(\varepsilon_b - 0\right)\right]$$

$$Cov_{a,b} = \beta_{Ma}\beta_{Mb}\sigma^2_{MRP} + \beta_{Ma}\beta_{Sb}Cov_{MRP,SMB} + \beta_{Ma}\beta_{Hb}Cov_{MRP,HML} + \beta_{Sa}\beta_{Mb}Cov_{MRP,SMB} + \beta_{Sa}\beta_{Sb}\sigma^2_{SMB} + \beta_{Sa}\beta_{Hb}Cov_{SMB,HML} + \beta_{Ha}\beta_{Mb}Cov_{MRP,HML} + \beta_{Ha}\beta_{Sb}Cov_{HML,SMB} + \beta_{Ha}\beta_{Hb}\sigma^2_{HML}$$

$$Cov_{a,b} = \beta_{Ma}\beta_{Mb}\sigma^2_{MRP} + \beta_{Sa}\beta_{Sb}\sigma^2_{SMB} + \beta_{Ha}\beta_{Hb}\sigma^2_{HML} + Cov_{MRP,SMB}\left(\beta_{Ma}\beta_{Sb} + \beta_{Sa}\beta_{Mb}\right) + Cov_{MRP,HML}\left(\beta_{Ma}\beta_{Hb} + \beta_{Ha}\beta_{Mb} + Cov_{SMB,HML}\left(\beta_{Sa}\beta_{Hb} + \beta_{Ha}\beta_{Sb}\right)\right) \tag{15}$$

3.8 Portfolio Performance Comparison

One year out of sample stock return is put into sets of global minimum variance optimal portfolios formed with 4 methods, namely Markowitz, CAPM, Fama-French, and Equally Weighted portfolio, in order to calculate the out of sample return. After the out of sample return calculation, a pair t-test is used to measure the different deviation in empirical test results to determine whether they are significantly different.

This research uses the Treynor ratio instead of the Sharpe ratio to measure portfolio performance because it is a risk adjusted measure of stock return based on market risk. Additionally, current and historical information does not affect the future data, but characteristics of assets can be used to estimate future data. Thus using the Treynor ratio represents performance in terms of the modeling view. Unfortunately, the Treynor Ratio is not applicable because there are 3 portfolio betas generated from the Fama French 3 Factors Model. Additionally, there is no beta in the Markowitz optimal portfolio and naïve portfolio. Thus, out of sample portfolio beta is calculated with regression between expected portfolio return generated and market return.

CHAPTER IV
PORTFOLIO RE-SAMPLING APPROACH (PRESA)

The optimal portfolio construction process is far more difficult when the number of assets is large. The grid-computing technique has been used to overcome this limitation. Unfortunately, retail investors do not have grid-computing technology at their home, so they cannot apply the optimal portfolio selection theory in the real situations.

This chapter will propose the new technique called the Portfolio Re-Sampling Approach (PRESA) to enable a home computer to apply the optimal portfolio theory in the real stock market.

4.1 Objective of PRESA

The optimization process is a complex algorithm to maximize or minimize the target value. For portfolio selection, linear programming and quadratic programming are applied to find the combination of weight invested in each stock in order to get the portfolio generating the highest return at a given level of risk, and vice versa.

Implementing linear programming and quadratic programming on home computers for a small set of assets to find the optimal portfolios is possible but investors will need a super computer or grid computing for a large number of assets. PRESA has been developed to enable home computers to find an optimal portfolio for large number of assets.

4.2 PRESA Methodology

The following are the 6 steps of PRESA:

1. Randomize the position of assets
2. Select the first sampling group with any number of stock
3. Construct the optimal portfolio by using linear programming for sampling group in step 1
4. Filter out stocks with zero asset allocation in step 2
5. Combine the remaining stocks with the new sampling group with any number of stock
6. Repeat steps 3 – 5 until all assets are involved in the process

The first step can be omitted on the assumption that the position of the assets does not affect the optimal portfolio return. In the third step, this method still utilizes benefits from linear programming and quadric programming to get the optimal solution. The second and forth step are used to eliminate linear programming and quadric programming drawbacks related to the number of assets. Steps 5 and 6 are used for including all assets in the optimization process.

4.2 PRESA Validation Methodology

PRESA Validation is conducted to test whether the position of assets will not significantly affect the portfolio return. The test generates 1000 sets of Markowitz optimal portfolio by using the full PRESA (including step 1 which is to randomize the assets' position), and then compares sample portfolio returns with the pair t-test.

4.3 PRESA Validation Result

Regarding Table 4.1 testing results, only 38,254, which is 8% of the pair t-test result, shows any significant difference in portfolio return from 499,000 pair t-test results, from which can be implied that the position of assets will not significantly affect the portfolio return in portfolio optimization using the PRESA technique. Additionally, figure 4.1 illustrates 1,000 returns of optimal portfolios generated by

PRESA with random position of assets. Most of the portfolio returns are at the same level.

Table 4.1 Pair T-Test result in PRESA Validation Testing

	Number	Percent
Not Significant	460,755	92%
Significant	38,245	8%
Total	499,000	100%

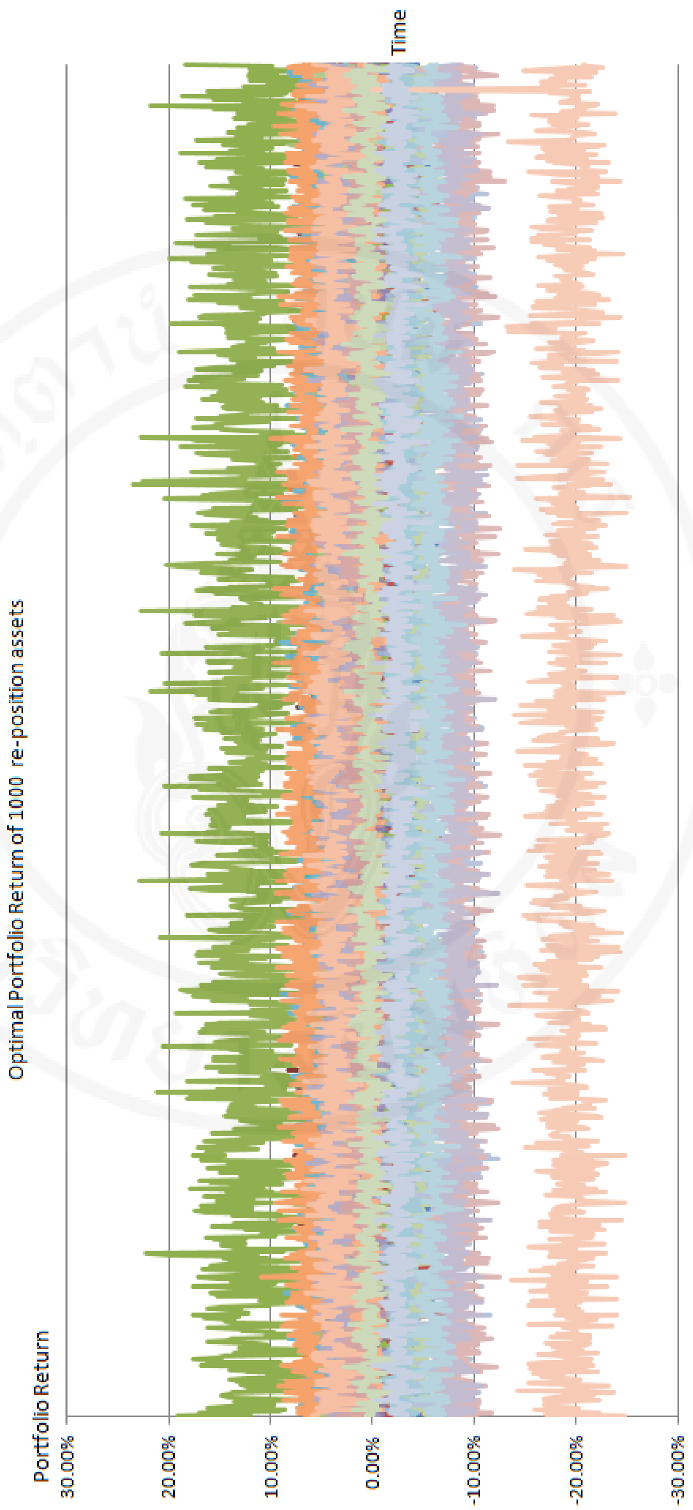


Figure 4.1 Optimal Portfolio Return of 1,000 re-position asset in PRESA Validation

CHAPTER V
RESULTS

This chapter will cover empirical results from the methodologies in chapter 3. There are 3 parts. The first section is the results from data screening. The second is the results from optimal portfolio selection, and the last part is portfolio performance measurement.

5.1 Data

Table 5.1 shows the number of valid stock by country. One of the main problems from most of the data being filtered out is that stocks have not been traded for more than 3 consecutive months or have been delisted. Another main reason is secondary stocks, for example, B-Share in China. Even though the number of valid stocks is less than half the number of total stock, simple linear programming on a low-end computer set could not generate any optimal portfolio. The number of stocks that will be included in the 3-year historical data optimal portfolio construction for out of sample portfolios in 2003, 2004, 2005, 2006, 2007, and 2008 are 4251, 3969, 4251, 4351, 4452, and 4557 respectively, and the number of stocks that will be included in the 5-year historical data optimal portfolio construction for out of sample portfolios in 2003, 2004, 2005, 2006, 2007, and 2008 are 1864, 2148, 3425, 3959, 4241, and 4336 respectively.

5.2 Optimal Portfolio Construction

Thanks to the portfolio re-sampling approach (PRESA) technique, a low-end computer set can create sets of optimal portfolios with 3 models, which are Markowitz, CAPM, and the Fama-French 3 Factors Model. Thirty-six optimal portfolios can be constructed within 10 hours. Figures 5.1-5.3 present examples of efficient frontiers of optimal portfolios constructed by the 3 models. All efficient frontiers are included in appendix I.

Regarding 36 efficient frontiers, the Fama-French 3 Factors Model generates the highest global minimum variance portfolio in sample data sets.

Table5.1 Number of Valid Stock by Country

Country	All	3 Years Historical Optimal Portfolio						5 Years Historical Optimal Portfolio					
		2003	2004	2005	2006	2007	2008	2003	2004	2005	2006	2007	2008
Argentina	89	56	57	56	55	54	51	32	41	53	55	53	50
Brazil	643	348	342	348	350	372	376	116	151	320	341	347	350
Chile	223	166	162	166	178	178	179	74	102	159	162	165	177
China	1,896	849	848	849	850	850	850	92	102	813	847	849	849
Colombia	29	13	13	13	15	14	14	11	12	12	13	13	14
India	1,046	304	277	304	320	369	432	210	215	235	276	304	319
Indonesia	436	228	227	228	228	228	228	148	151	189	227	228	228
Israel	126	65	60	65	70	71	83	29	42	48	59	62	67
Malaysia	978	531	502	531	539	551	558	313	318	350	502	531	539
Mexico	184	105	100	105	108	111	111	60	79	94	98	104	106
Pakistan	125	80	76	80	84	85	86	56	61	69	76	80	84
Peru	79	68	66	68	72	76	76	33	43	55	66	68	72
Philippines	110	108	103	108	108	108	108	66	74	87	103	108	108
Russia	108	37	35	37	44	48	63	23	27	29	35	37	44
SouthAfrica	413	240	240	240	242	245	246	82	189	232	238	240	242
SriLanka	37	29	28	29	30	31	31	17	18	22	28	29	30
Taiwan	1,315	538	359	538	549	550	550	186	189	296	359	538	549
Thailand	811	325	323	325	326	326	326	225	226	233	323	325	326
Turkey	271	144	134	144	166	168	172	82	97	114	134	143	165
Venezuela	47	17	17	17	17	17	17	9	11	15	17	17	17
Total	8,966	4,251	3,969	4,251	4,351	4,452	4,557	1,864	2,148	3,425	3,959	4,241	4,336

Figure5.1 Optimal Portfolio 3 years historical data(Dec 1999 - Dec 2002) with Markowitz Method

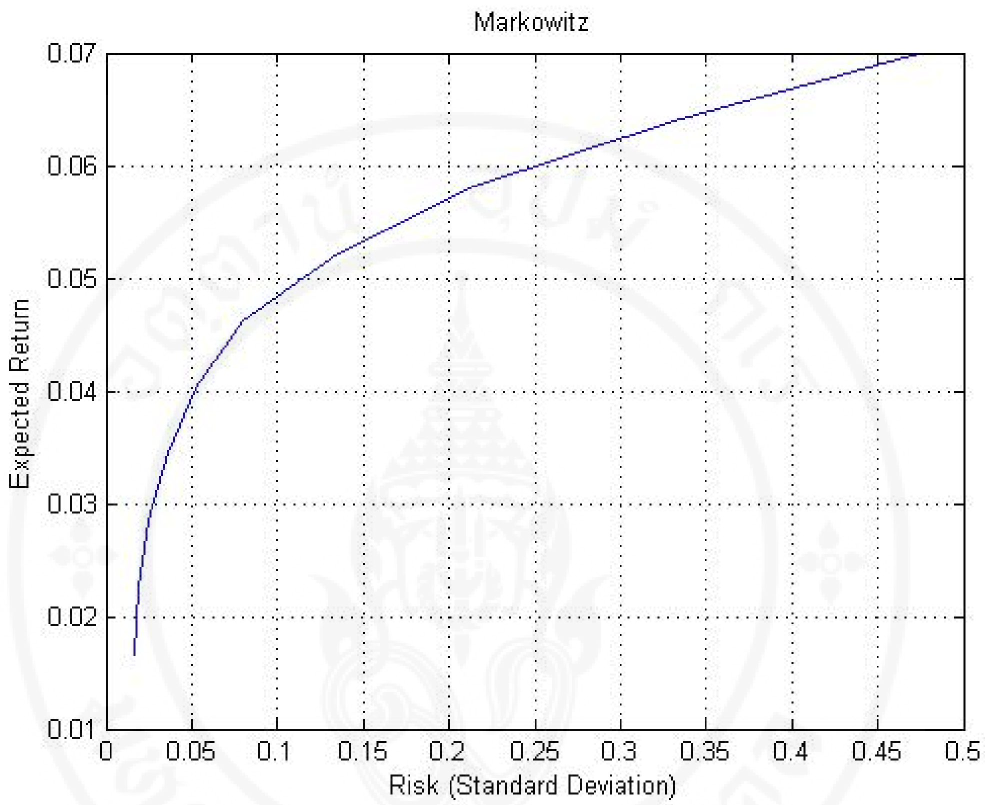


Figure5.2 Optimal Portfolio 3 years historical data(Dec 1999 - Dec 2002) with CAPM Method

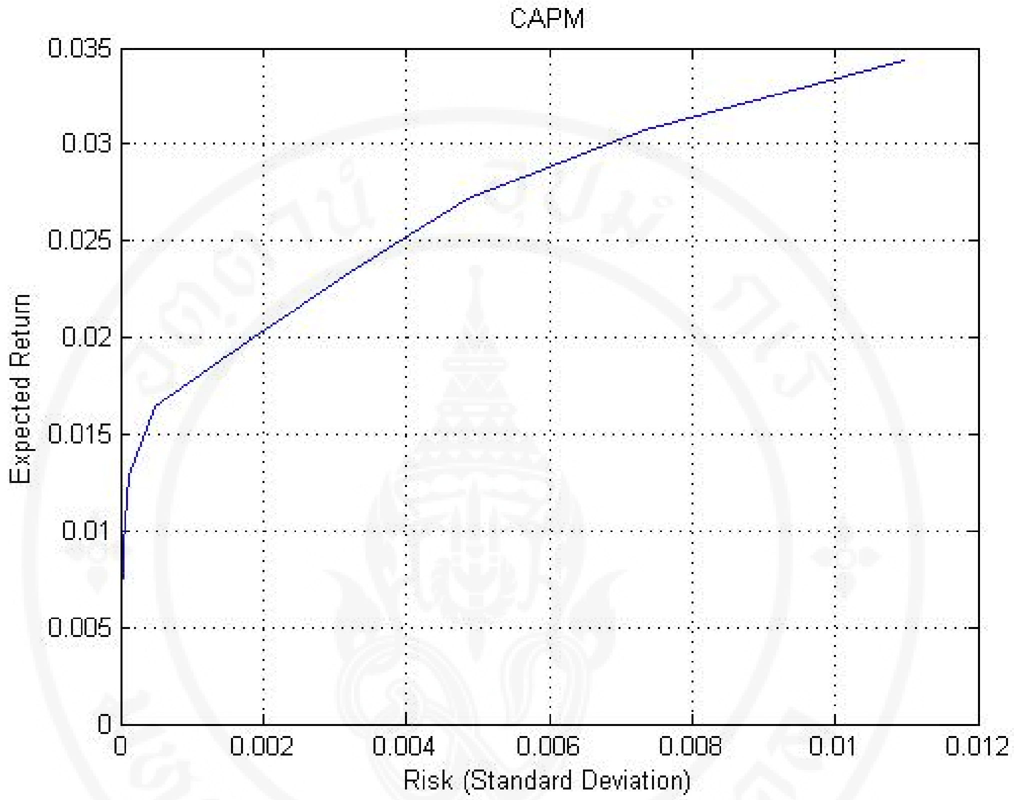
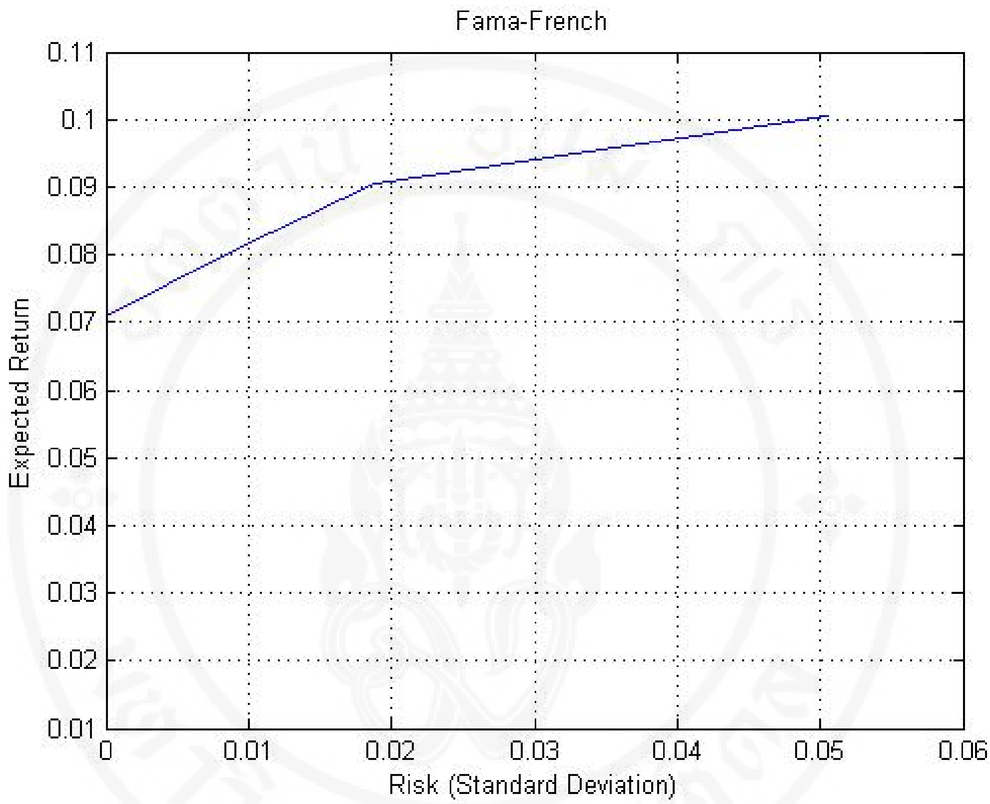


Figure5.3 Optimal Portfolio 3 years historical data(Dec 1999 - Dec 2002) with Fama-French 3 Factors Model Method



5.3 Out of Sample Return

Twelve monthly out of sample returns are substituted in optimal asset allocations from global minimum variance portfolios formed by the 3 methods and Naïve portfolio with the rolling window technique. Table 5.2 shows monthly return on out of sample portfolios.

Table5.2 Monthly Return on Out of Sample Portfolio

M = Markowitz Method

C =CAPM Method

F=Fama-French 3 Factors Method

E=Naïve Portfolio

Month	3 Years Historical Optimal Portfolio				5 Years Historical Optimal Portfolio			
	M	C	F	E	M	C	F	E
2003-01	0.59%	0.25%	6.39%	-1.62%	-1.34%	-7.96%	3.12%	-3.24%
2003-02	-8.73%	-20.40%	-3.94%	2.74%	-0.71%	-11.56%	1.24%	-0.32%
2003-03	8.05%	1.20%	-5.95%	0.00%	1.58%	1.45%	-5.81%	-1.55%
2003-04	-3.83%	24.04%	7.49%	-2.23%	-19.38%	-15.93%	5.18%	-4.56%
2003-05	5.58%	2.37%	5.09%	2.73%	2.07%	5.34%	12.26%	6.56%
2003-06	11.09%	4.90%	-4.10%	5.45%	0.80%	20.83%	0.57%	8.98%
2003-07	7.57%	14.63%	7.19%	0.86%	4.56%	23.66%	0.85%	5.61%
2003-08	6.42%	-3.66%	-8.64%	0.97%	5.67%	-6.41%	2.10%	3.56%
2003-09	7.36%	0.80%	-3.61%	3.71%	12.91%	9.75%	1.28%	8.01%
2003-10	10.04%	-25.92%	6.52%	-0.94%	4.02%	-5.03%	4.71%	0.20%
2003-11	-1.62%	-1.64%	13.47%	0.30%	3.04%	0.91%	2.14%	4.17%
2003-12	-4.91%	2.36%	-3.86%	1.69%	-2.24%	14.68%	-4.96%	2.06%
2004-01	-2.14%	-4.04%	-4.18%	1.32%	2.43%	-0.96%	-7.12%	1.94%
2004-02	2.76%	-7.40%	-2.20%	4.18%	2.54%	1.62%	8.52%	4.66%
2004-03	7.63%	10.77%	-6.25%	0.00%	-0.02%	7.56%	3.94%	-0.82%
2004-04	-4.43%	7.89%	-2.66%	3.40%	4.93%	2.11%	-2.57%	3.43%
2004-05	1.74%	3.29%	-0.38%	-0.11%	4.06%	1.74%	0.38%	0.91%
2004-06	-4.50%	-11.38%	-6.39%	-5.66%	-4.66%	5.61%	-10.18%	-4.89%
2004-07	-2.84%	-1.48%	-23.20%	-5.05%	-1.42%	0.35%	-8.08%	-5.93%
2004-08	0.32%	-15.82%	2.60%	-0.13%	0.83%	-3.50%	1.30%	0.55%
2004-09	-0.11%	-13.17%	-5.50%	-1.01%	-0.38%	-2.96%	5.96%	-0.19%
2004-10	2.10%	-6.27%	9.12%	3.90%	-0.52%	-4.98%	4.77%	3.14%
2004-11	6.12%	3.57%	12.34%	5.26%	3.49%	3.15%	8.17%	5.29%
2004-12	-4.08%	1.30%	-6.30%	0.41%	0.16%	-3.20%	-4.81%	0.91%
2005-01	4.80%	9.64%	-0.71%	7.55%	5.79%	2.64%	0.25%	8.25%
2005-02	0.98%	0.22%	10.09%	5.41%	1.24%	-1.17%	5.11%	4.60%
2005-03	3.47%	-9.09%	0.91%	1.87%	1.67%	-28.95%	-2.76%	0.74%
2005-04	5.61%	9.10%	7.06%	5.95%	5.65%	14.47%	6.79%	5.62%
2005-05	-9.38%	-9.23%	-11.58%	-4.40%	-0.66%	3.58%	-8.26%	-3.89%
2005-06	-6.00%	-4.21%	-2.40%	-4.31%	-1.48%	-1.51%	3.98%	-3.85%
2005-07	0.11%	-9.36%	14.18%	-0.47%	0.07%	-8.90%	4.73%	-0.65%
2005-08	0.67%	0.88%	-14.07%	2.96%	3.30%	2.50%	1.22%	2.43%
2005-09	2.32%	5.96%	18.46%	3.19%	2.45%	6.91%	-3.71%	3.76%
2005-10	1.49%	8.90%	-1.20%	-0.33%	7.16%	12.56%	3.04%	2.12%
2005-11	-0.73%	2.92%	11.76%	3.75%	5.40%	-2.47%	6.87%	4.45%
2005-12	1.05%	-9.13%	0.20%	-4.27%	1.71%	9.35%	4.55%	-4.36%
2006-01	3.27%	1.58%	-4.03%	5.20%	-0.69%	-1.63%	10.57%	5.11%
2006-02	8.16%	-2.96%	-3.83%	3.22%	0.75%	-2.89%	-5.86%	2.92%
2006-03	5.86%	6.69%	-3.10%	5.11%	4.88%	20.39%	9.86%	5.25%

Month	3 Years Historical Optimal Portfolio				5 Years Historical Optimal Portfolio			
	M	C	F	E	M	C	F	E
2006-04	-0.63%	-3.14%	-1.18%	1.93%	0.67%	-36.73%	3.44%	1.88%
2006-05	-4.24%	-7.83%	0.23%	1.36%	0.51%	10.71%	3.34%	2.10%
2006-06	8.06%	-3.62%	-0.53%	6.78%	3.57%	2.23%	1.81%	6.01%
2006-07	-6.97%	-17.30%	-1.35%	-9.27%	-2.97%	23.06%	-15.71%	-9.45%
2006-08	-3.70%	0.62%	-0.32%	-3.01%	-0.85%	-8.70%	4.84%	-2.83%
2006-09	1.15%	-18.54%	2.02%	-1.70%	0.68%	17.67%	-6.13%	-1.20%
2006-10	1.01%	5.97%	-2.16%	3.11%	0.98%	17.03%	4.96%	3.68%
2006-11	2.95%	8.23%	4.71%	2.10%	-0.25%	7.82%	1.18%	2.17%
2006-12	5.68%	8.49%	3.57%	5.30%	2.76%	-10.94%	-0.01%	5.17%
2007-01	6.41%	3.16%	-0.01%	6.04%	4.58%	-2.42%	-4.70%	6.45%
2007-02	2.63%	-25.68%	8.97%	3.58%	1.83%	3.14%	6.70%	3.24%
2007-03	-1.92%	11.92%	-0.47%	3.10%	-0.83%	10.84%	4.13%	1.68%
2007-04	3.09%	-3.15%	7.47%	0.94%	1.28%	8.19%	-15.56%	0.72%
2007-05	0.40%	3.59%	8.67%	4.53%	1.94%	17.72%	4.37%	3.63%
2007-06	-1.32%	19.97%	4.76%	8.09%	-0.23%	26.80%	4.39%	6.54%
2007-07	7.27%	9.84%	7.38%	8.14%	1.32%	0.06%	4.80%	7.35%
2007-08	3.34%	4.52%	-3.13%	4.25%	0.49%	-7.32%	5.47%	5.08%
2007-09	4.39%	3.12%	-2.09%	3.72%	3.17%	4.24%	16.25%	3.16%
2007-10	0.62%	-1.89%	-4.62%	-2.12%	-0.90%	10.58%	-15.55%	-3.34%
2007-11	2.01%	8.67%	2.18%	6.29%	1.35%	5.93%	1.71%	6.41%
2007-12	-1.16%	5.62%	0.93%	0.67%	-0.14%	-13.72%	-0.54%	1.25%
2008-01	-6.74%	-1.62%	2.70%	-4.99%	-4.47%	-5.15%	-15.87%	-5.85%
2008-02	-3.60%	19.53%	-3.80%	4.45%	-0.71%	14.52%	-0.55%	2.56%
2008-03	-7.45%	8.97%	-5.14%	-9.97%	-3.57%	8.98%	-3.69%	-9.30%
2008-04	7.28%	1.20%	7.11%	4.77%	1.60%	13.73%	5.35%	3.41%
2008-05	0.91%	1.33%	-3.32%	-9.32%	-2.30%	-16.59%	-5.39%	-6.43%
2008-06	1.55%	0.35%	-2.67%	3.07%	0.22%	30.06%	2.52%	3.36%
2008-07	-0.11%	0.78%	-5.31%	-2.00%	-0.52%	-3.54%	4.46%	-1.95%
2008-08	-10.96%	1.08%	1.79%	-15.41%	-6.52%	-31.45%	-7.39%	-13.12%
2008-09	-3.43%	0.22%	1.13%	1.73%	2.43%	-4.79%	-0.75%	0.48%
2008-10	-1.87%	0.24%	-2.78%	-12.92%	-4.33%	-38.50%	-17.26%	-10.58%
2008-11	-10.56%	-44.27%	-6.14%	-14.02%	-5.76%	5.51%	-21.47%	-14.71%
2008-12	-17.72%	-57.88%	-26.96%	-30.41%	-18.55%	-57.99%	-25.58%	-29.75%

Comparisons of the return on out of sample portfolios formed by different methods were evaluated by using the pair t-test method. Even though returns are not equal, there is no significant difference in out of sample portfolio returns.

Table 5.3 Pair T-Test between return on out of sample portfolio

	3 Years Historical Optimal Portfolio				5 Years Historical Optimal Portfolio			
	M	C	F	E	M	C	F	E
M	N/A	1.24	0.65	0.47	N/A	0.23	0.88	0.08
C	1.24	N/A	0.8	1.12	0.23	N/A	0.63	0.21
F	0.65	0.8	N/A	0.37	0.88	0.63	N/A	0.69
E	0.47	1.12	0.37	N/A	0.08	0.21	0.69	N/A

According to Table 5.4, Naïve portfolio beta has the smallest deviation. The CAPM method generated out of sample portfolio beta with the highest deviation.

Table 5.4 Out of Sample Portfolio Beta

Year	3 Years Historical Optimal Portfolio				5 Years Historical Optimal Portfolio			
	M	C	F	E	M	C	F	E
2003	0.65	-0.04	0.17	0.35	1.02	1.81	0.36	0.94
2004	0.42	0.77	1.24	0.72	0.48	-0.09	0.95	0.70
2005	0.60	1.23	1.06	0.81	0.39	0.26	0.32	0.81
2006	0.68	1.13	-0.14	0.76	0.30	-0.68	1.08	0.76
2007	-0.04	0.63	0.10	0.34	0.03	-0.87	0.70	0.42
2008	0.57	1.76	0.60	0.96	0.49	1.80	0.88	0.92
SD	0.27	0.61	0.56	0.25	0.33	1.18	0.32	0.19

5.4 Portfolio Performance Measurement

The quantitative method used to rank portfolio performance in this research is Treynor Ratio. The best portfolio has Treynor ratio equal to 0.04 on average, which is out of the sample portfolios formed by using the Fama-French 3 Factors Model with 3-year historical data.

Table5.5 Out of Sample Portfolio Treynor Ratio

Year	3 Years Historical Optimal Portfolio				5 Years Historical Optimal Portfolio			
	M	C	F	E	M	C	F	E
2003	0.04	0.10	0.06	0.02	0.01	0.01	0.05	0.02
2004	0.00	-0.04	-0.03	0.00	0.01	-0.02	0.00	0.00
2005	0.00	-0.01	0.02	0.01	0.06	0.01	0.04	0.01
2006	0.02	-0.02	0.07	0.02	0.01	-0.04	0.01	0.02
2007	-0.47	0.05	0.21	0.10	0.25	-0.06	0.01	0.08
2008	-0.08	-0.04	-0.07	-0.08	-0.71	-0.30	-0.72	-0.75
Mean	-0.08	0.01	0.04	0.01	-0.06	-0.06	-0.10	-0.10

CHAPTER VI
DISCUSSION AND CONCLUSIONS

6.1 Discussion and Conclusions

The first chapter is about objectives, inspirations, and contributions. The frequently asked question from retail investors became the inspiration to find the answer with a systematic research method. Three capital asset pricing models, namely Markowitz , CAPM, and the Fama French three factors model, were used in this thesis. Two historical time frames, three and five years, were parameters used to find the appropriate number of historical observations. Linear programming was used for constructing optimal portfolios. Unfortunately, a home computer was not capable of performing linear programming in optimal portfolio selection with a large number of assets. Thus, this thesis introduced the PRESA technique to overcome this limitation.

The literature review and related academic knowledge were covered in chapter 2. It covered capital asset pricing models, optimal portfolio construction, portfolio measurement, and linear programming research. Research methodology and data screening processes were described in chapter 3.

Chapter 4 introduced the PRESA technique in detail with PRESA validation testing. As a result, this thesis proved that PRESA constructed the same level of portfolio performance for the same series of assets.

Empirical results were discussed in chapter 5. Out of sample portfolio performance was used as a KPI to measure performance of the optimal portfolio construction methods and number of historical observations.

In conclusion, three common difficulties for general investors are calculating the expected value of a security, the number of historical observations required to calculate the expected return, and asset allocation for a large number of assets. All of these problems were solved by this research. The portfolio re-sampling approach (PRESA) technique enables low-end computer sets, 800MHz 32-bit computer with 2 GB of RAM, to construct optimal portfolios. According to empirical test results, the sample portfolios formed by the Fama-French Three-factors Model with 36 monthly observations have the best Treynor Ratio.

6.2 Further Study

The following dimensions are further study ideas related to this thesis:

1. Adding a variety of historical time frames, which are 1-year, 2-year , 4-year, 6-year,7-year, 8-year, 9-year and 10-year for optimal portfolio construction.
2. Taking other capital asset pricing models into account
3. Comparison on optimal portfolios constructed with linear programming and PRESA

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APPENDIX

Optimal Portfolio Frontiers

Figure A1.1 Optimal Portfolio 3 years historical data(Dec 1999 - Dec 2002) with Markowitz Method

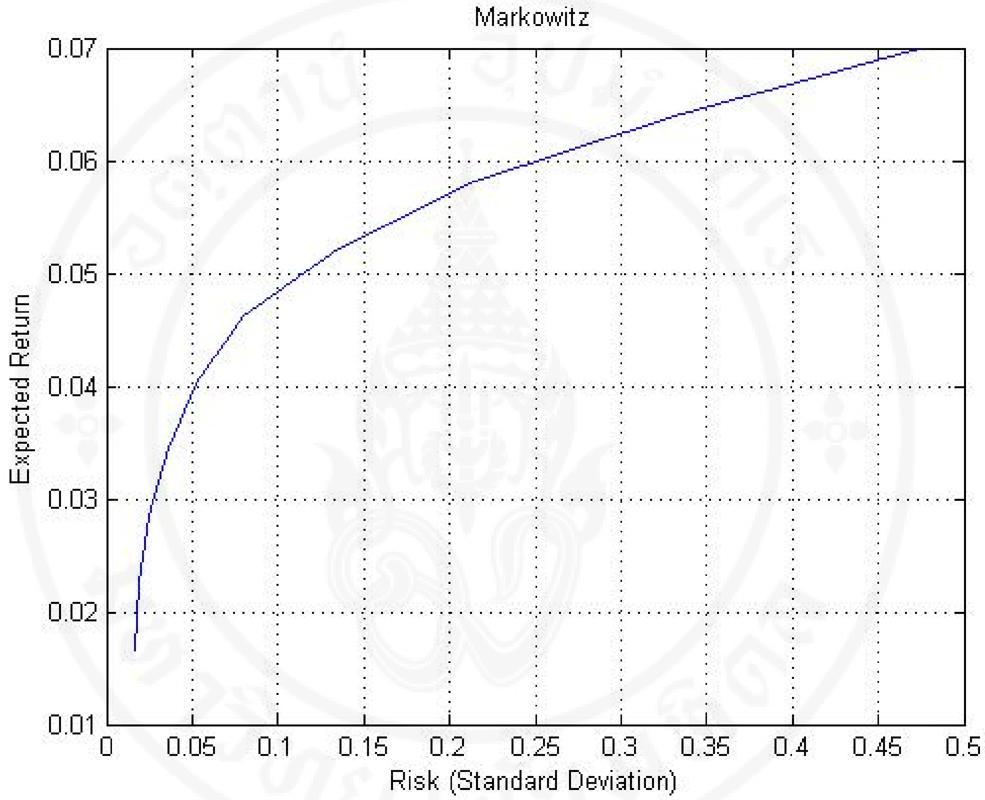


Figure A1.2 Optimal Portfolio 3 years historical data(Dec 1999 - Dec 2002) with CAPM Method

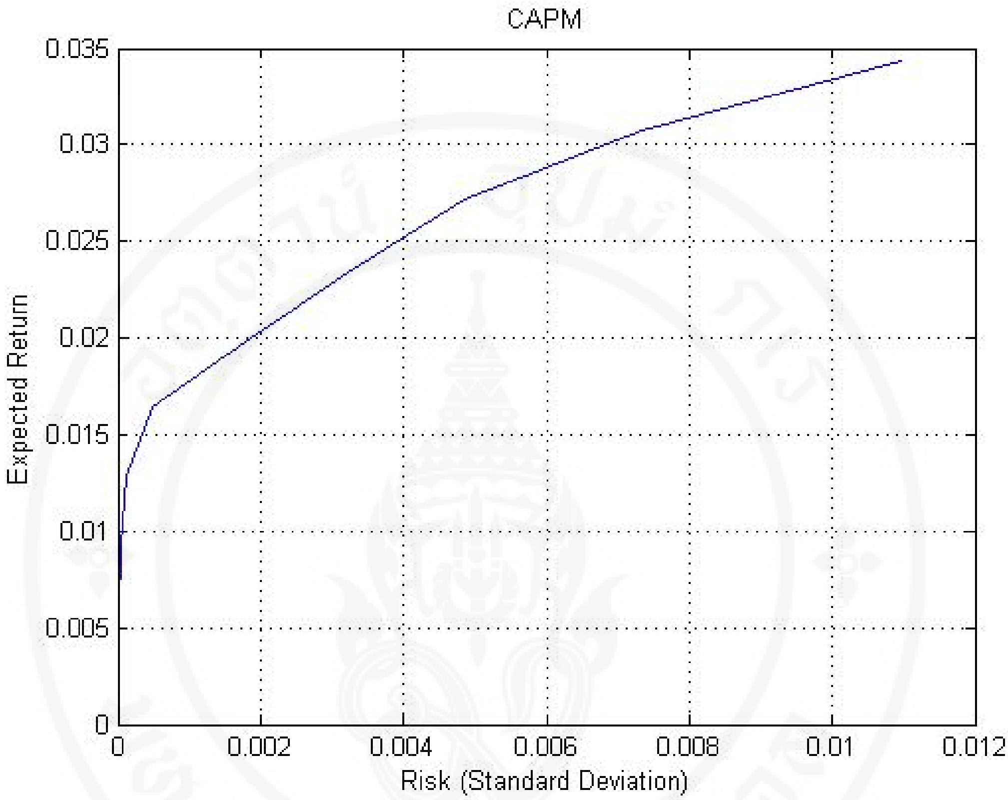


Figure A1.3 Optimal Portfolio 3 years historical data(Dec 1999 - Dec 2002) with Fama-French 3 Factors Model Method

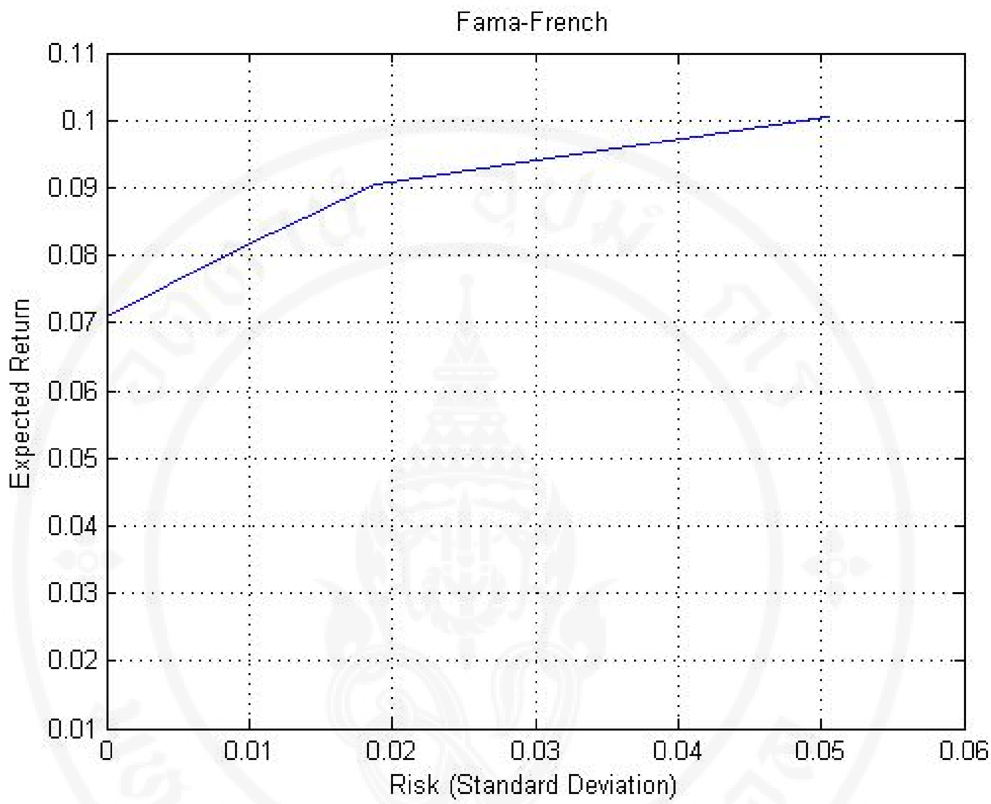


Figure A1.4 Optimal Portfolio 3 years historical data(Dec 2002 - Dec 2003) with Markowitz Method

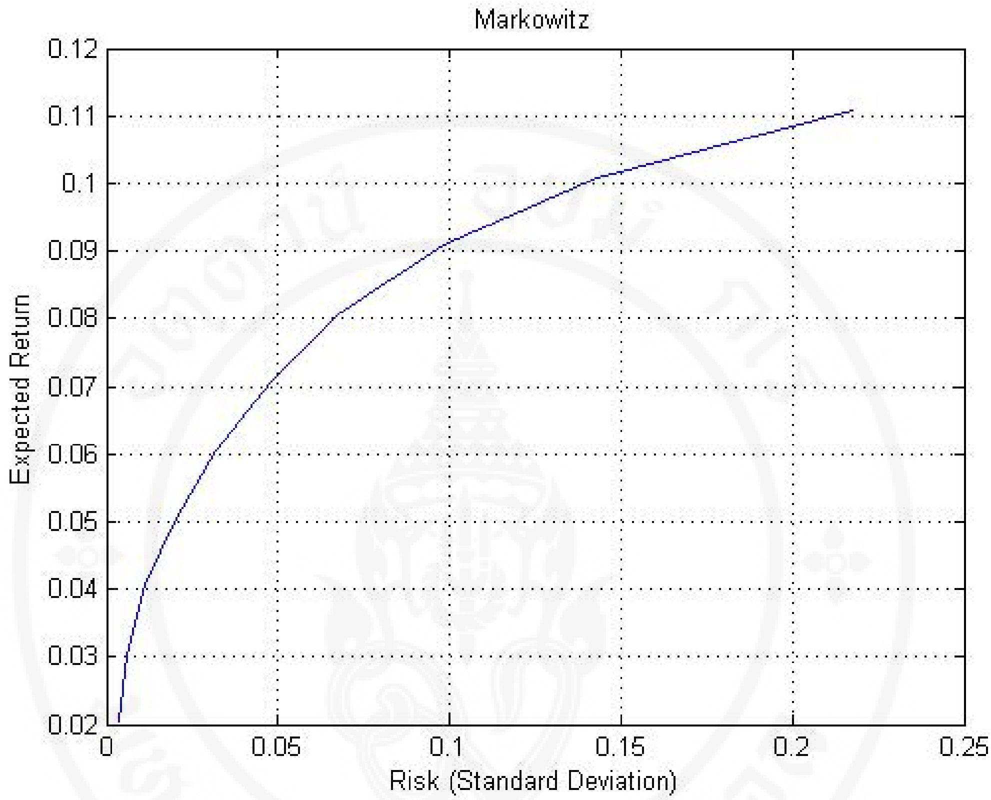


Figure A1.5 Optimal Portfolio 3 years historical data(Dec 2002 - Dec 2003) with CAPM Method

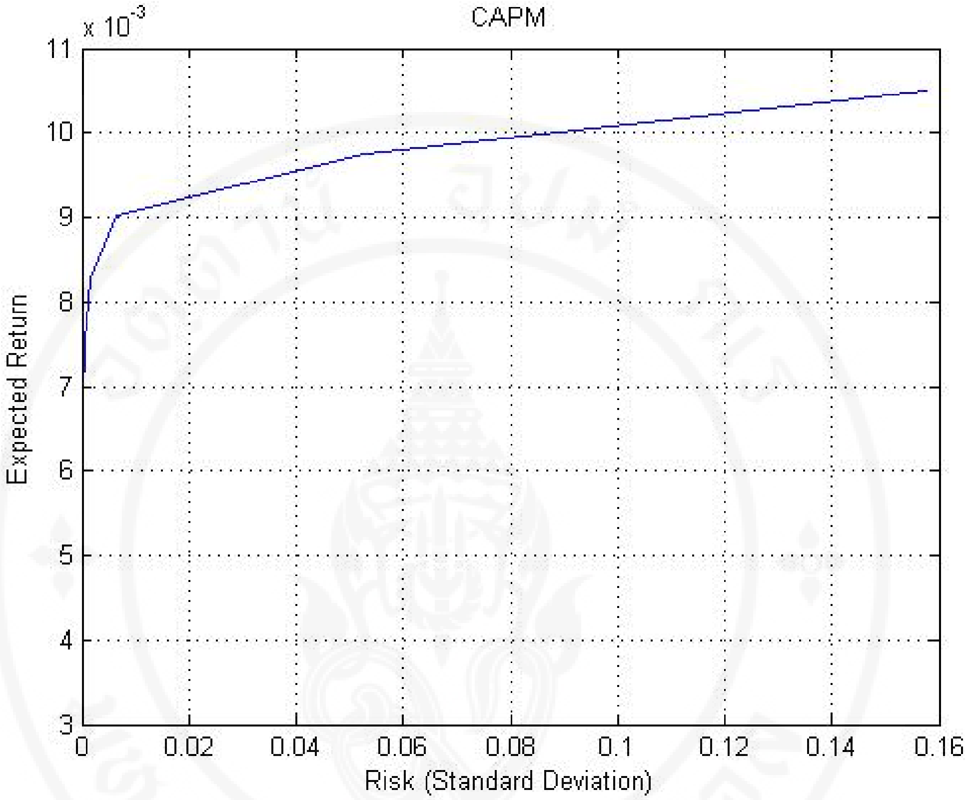


Figure A1.6 Optimal Portfolio 3 years historical data(Dec 2002 - Dec 2003) with Fama-French 3 Factors Model Method

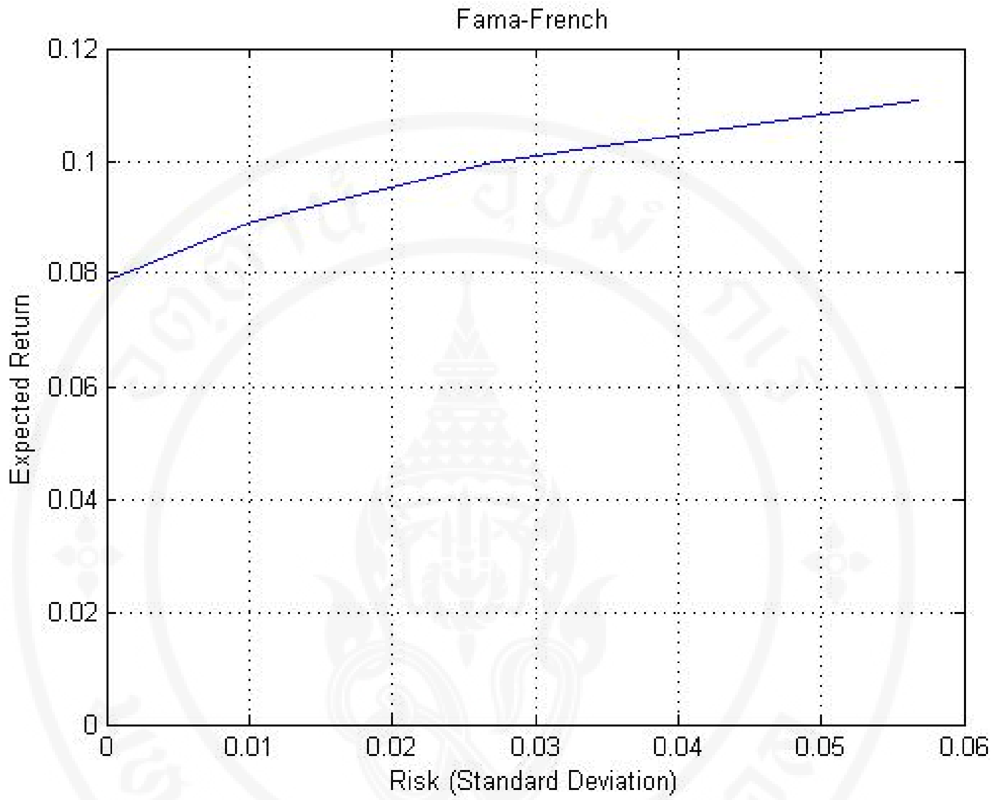


Figure A1.7 Optimal Portfolio 3 years historical data(Dec 2003 - Dec 2004) with Markowitz Method

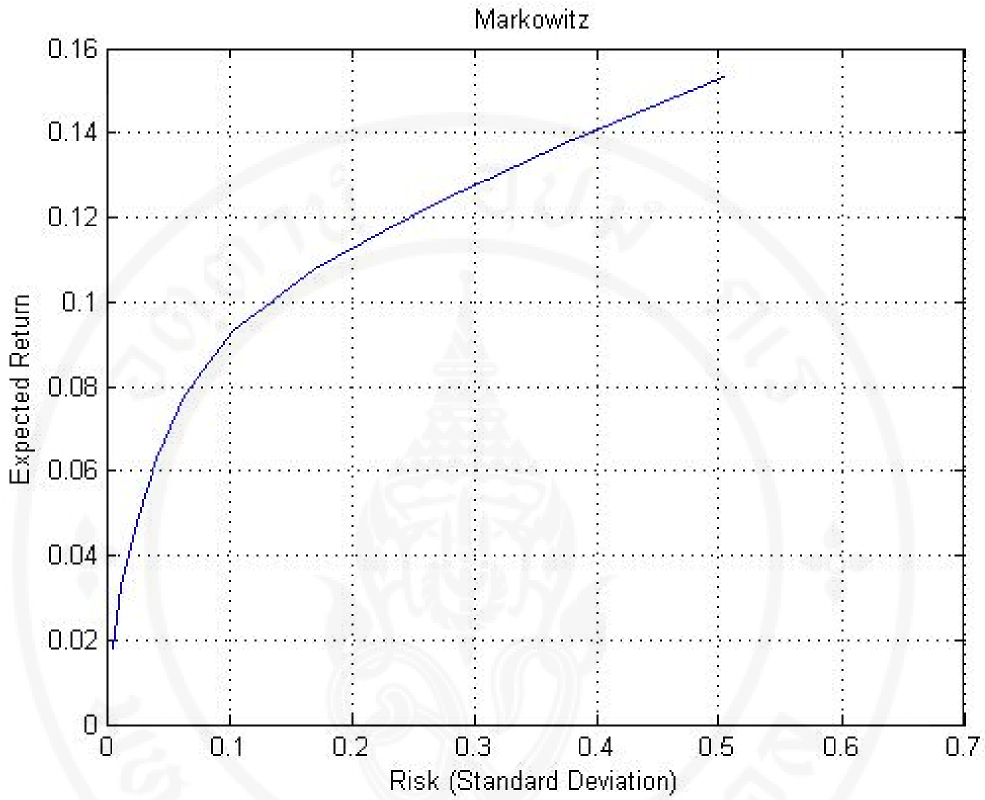


Figure A1.8 Optimal Portfolio 3 years historical data(Dec 2003 - Dec 2004) with CAPM Method

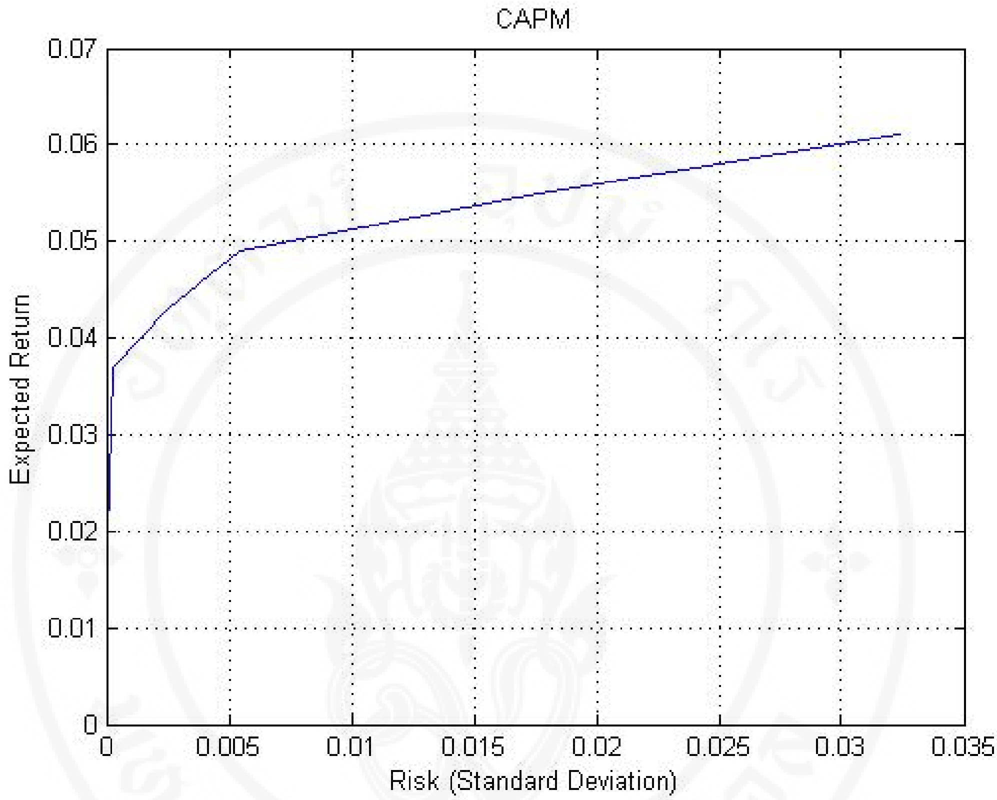


Figure A1.9 Optimal Portfolio 3 years historical data(Dec 2003 - Dec 2004) with Fama-French 3 Factors Model Method

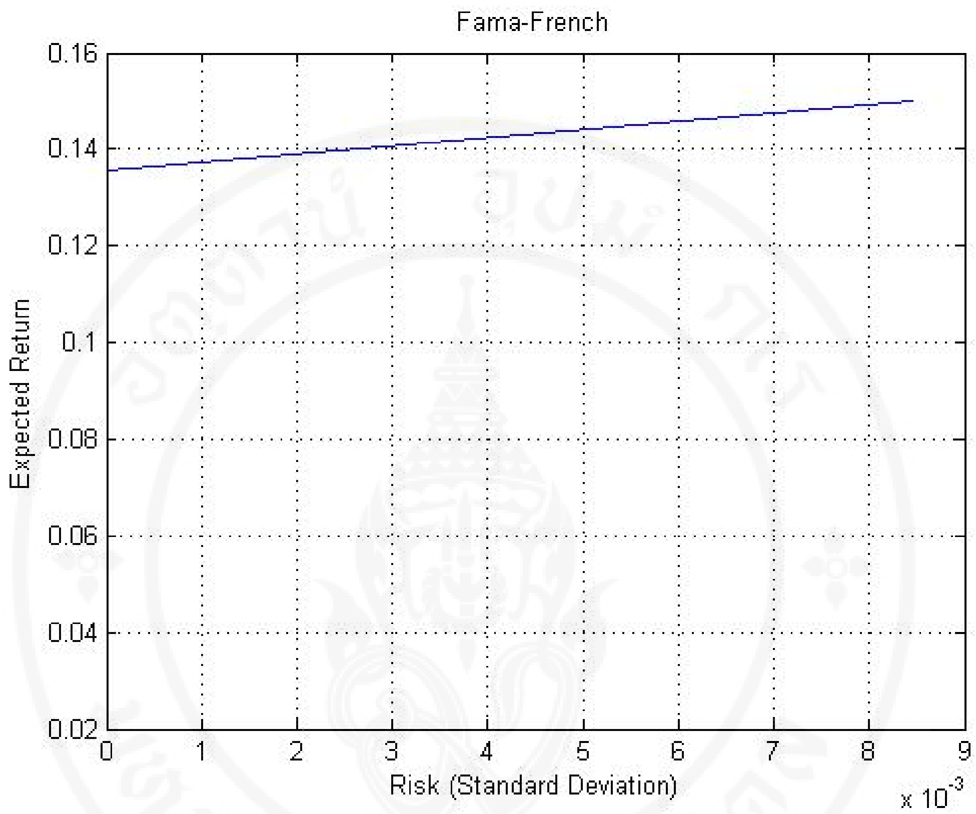


Figure A1.10 Optimal Portfolio 3 years historical data(Dec 2004 - Dec 2005) with Markowitz Method

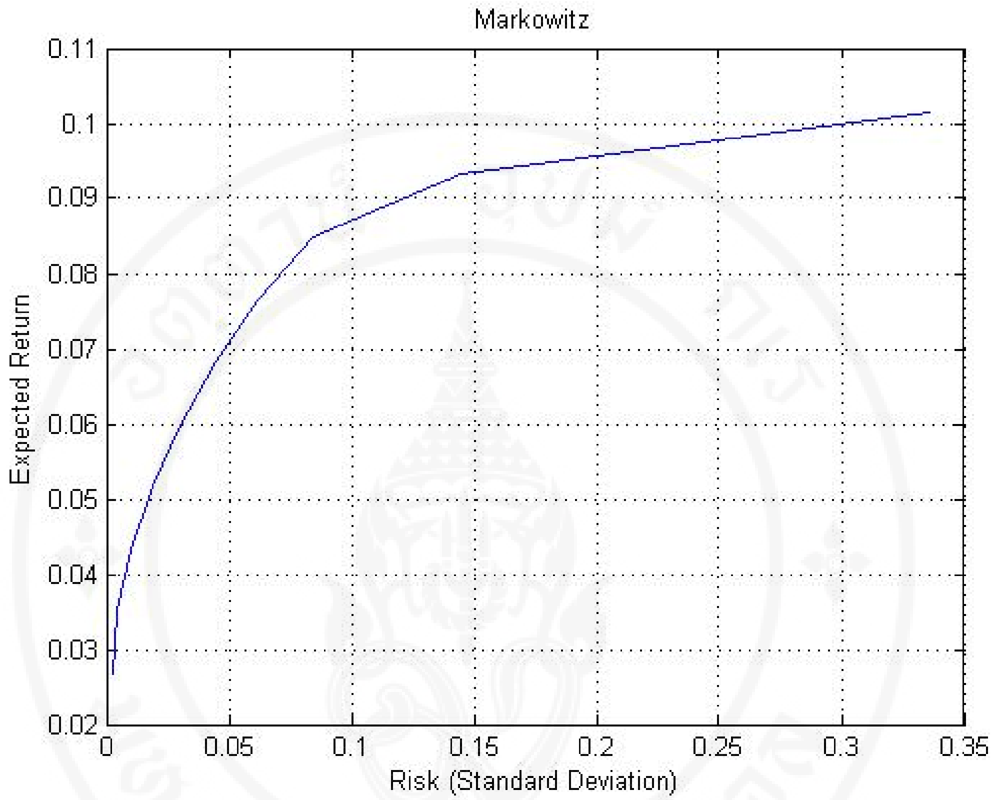


Figure A1.11 Optimal Portfolio 3 years historical data(Dec 2004 - Dec 2005) with CAPM Method

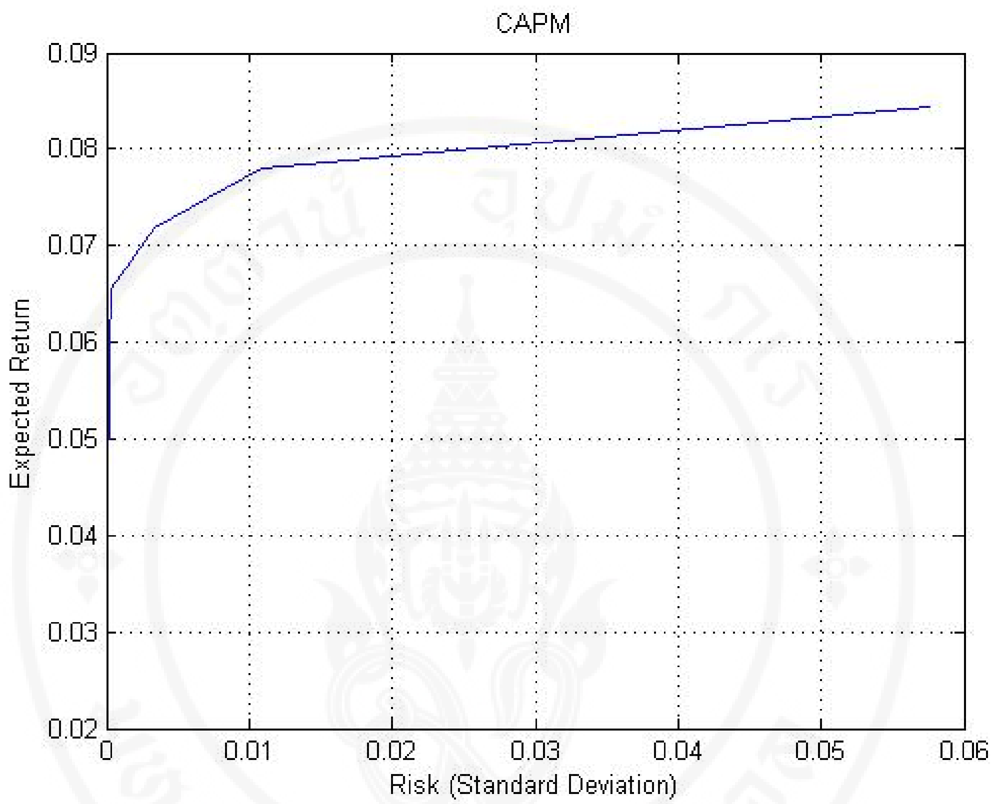


Figure A1.12 Optimal Portfolio 3 years historical data(Dec 2004 - Dec 2005) with Fama-French 3 Factors Model Method

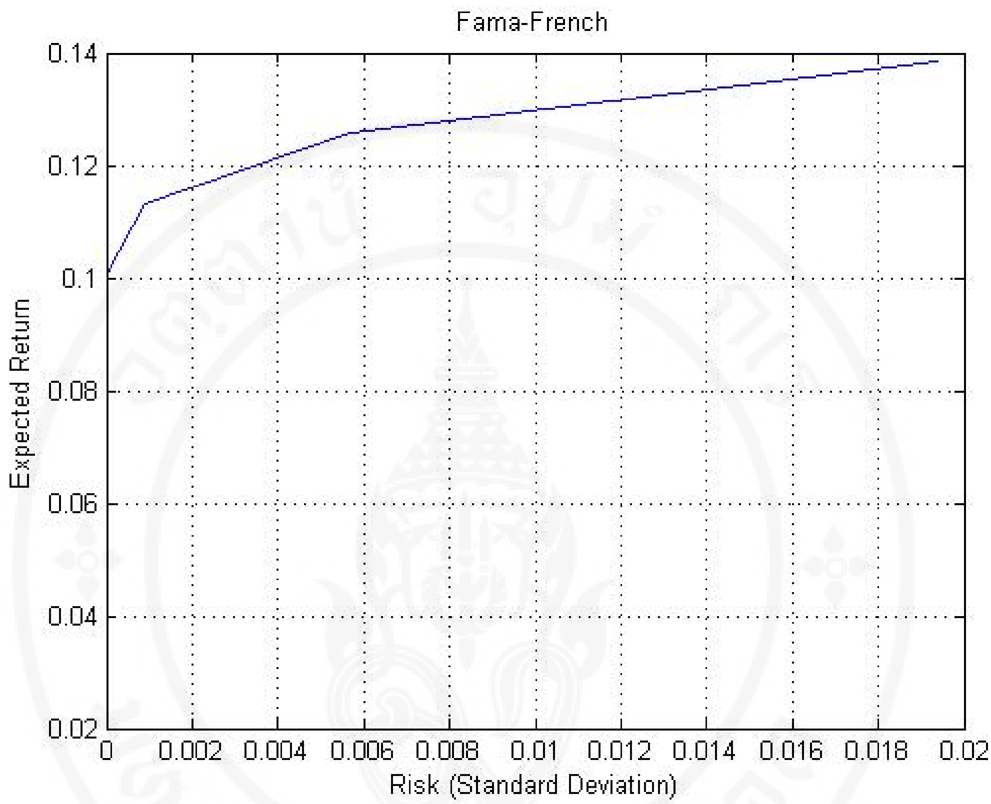


Figure A1.13 Optimal Portfolio 3 years historical data(Dec 2005 - Dec 2006) with Markowitz Method

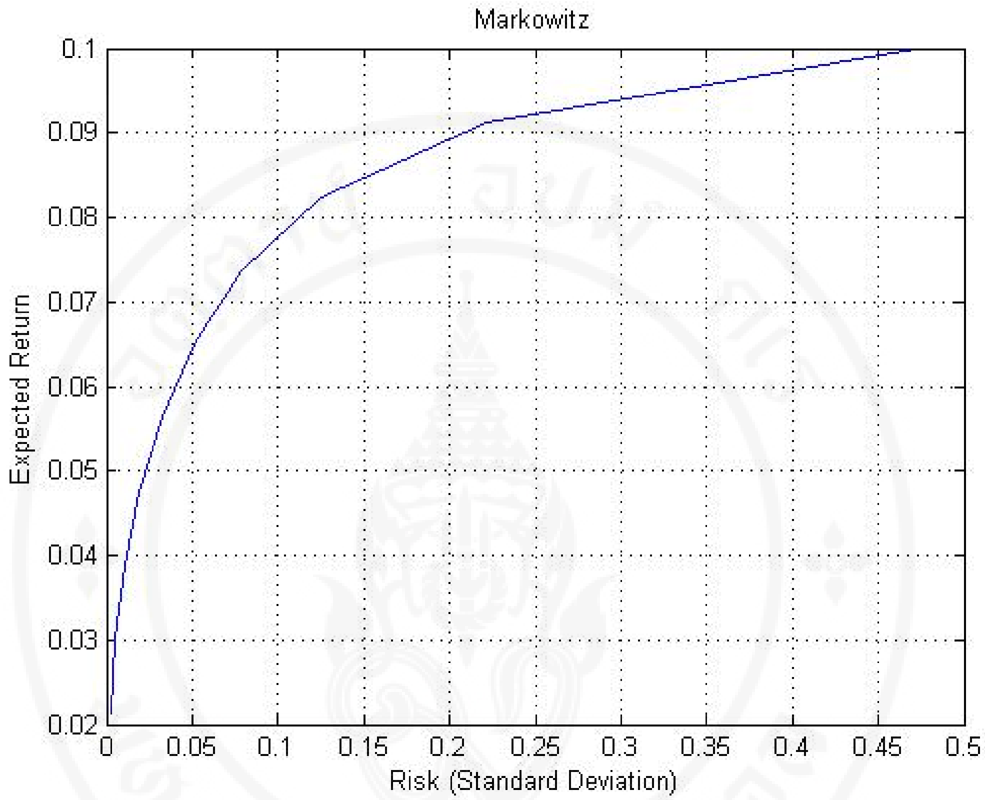


Figure A1.14 Optimal Portfolio 3 years historical data(Dec 2005 - Dec 2006) with CAPM Method

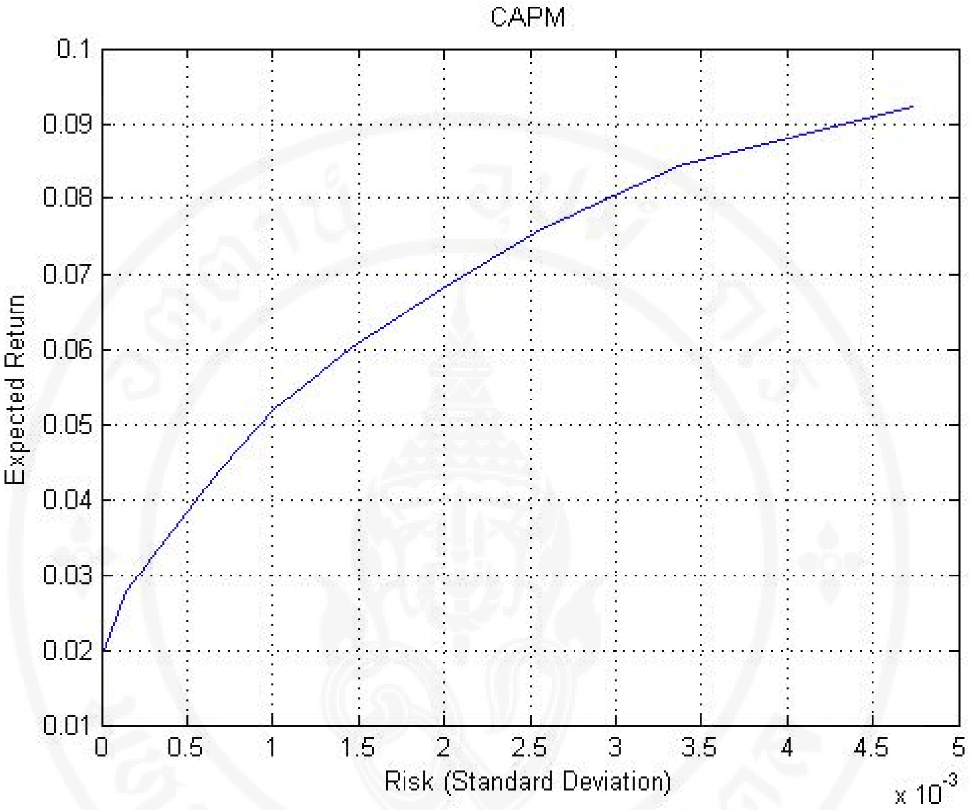


Figure A1.15 Optimal Portfolio 3 years historical data(Dec 2005 - Dec 2006) with Fama-French 3 Factors Model Method

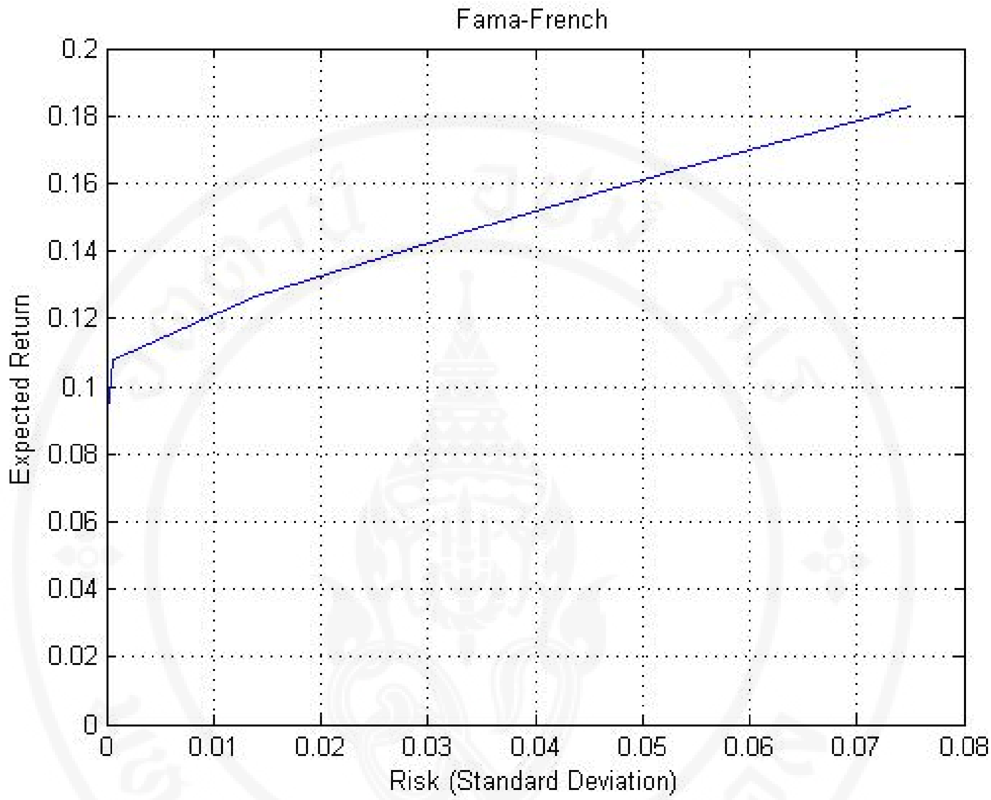


Figure A1.16 Optimal Portfolio 3 years historical data(Dec 2006 - Dec 2007) with Markowitz Method

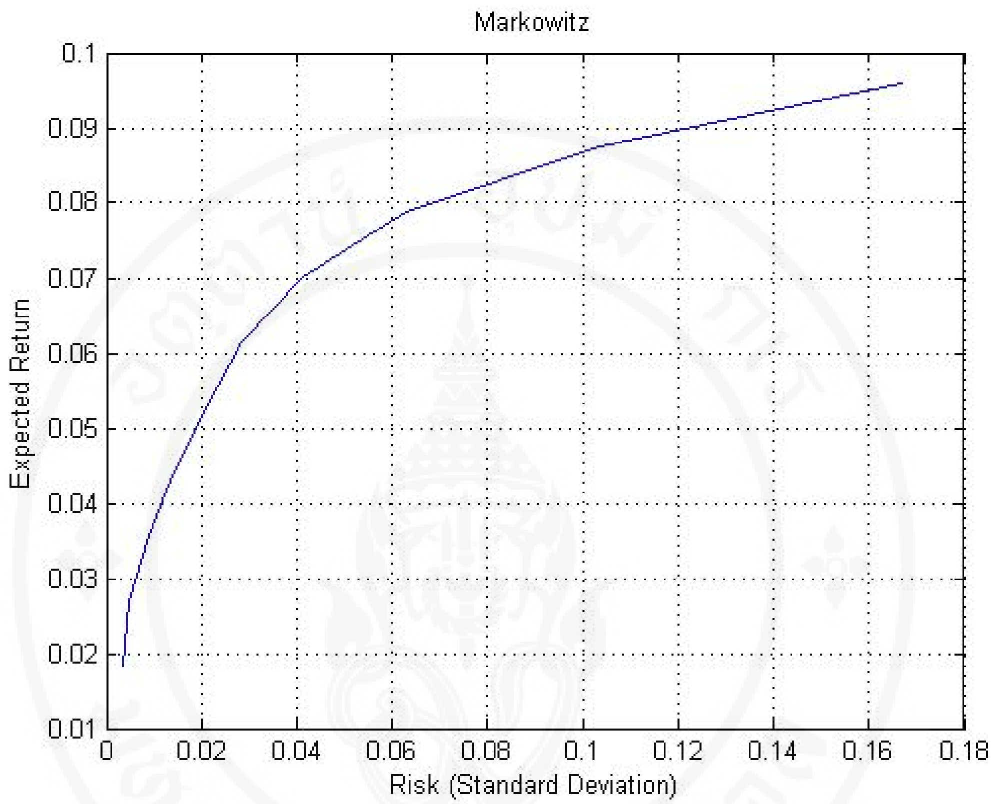


Figure A1.17 Optimal Portfolio 3 years historical data(Dec 2006 - Dec 2007) with CAPM Method

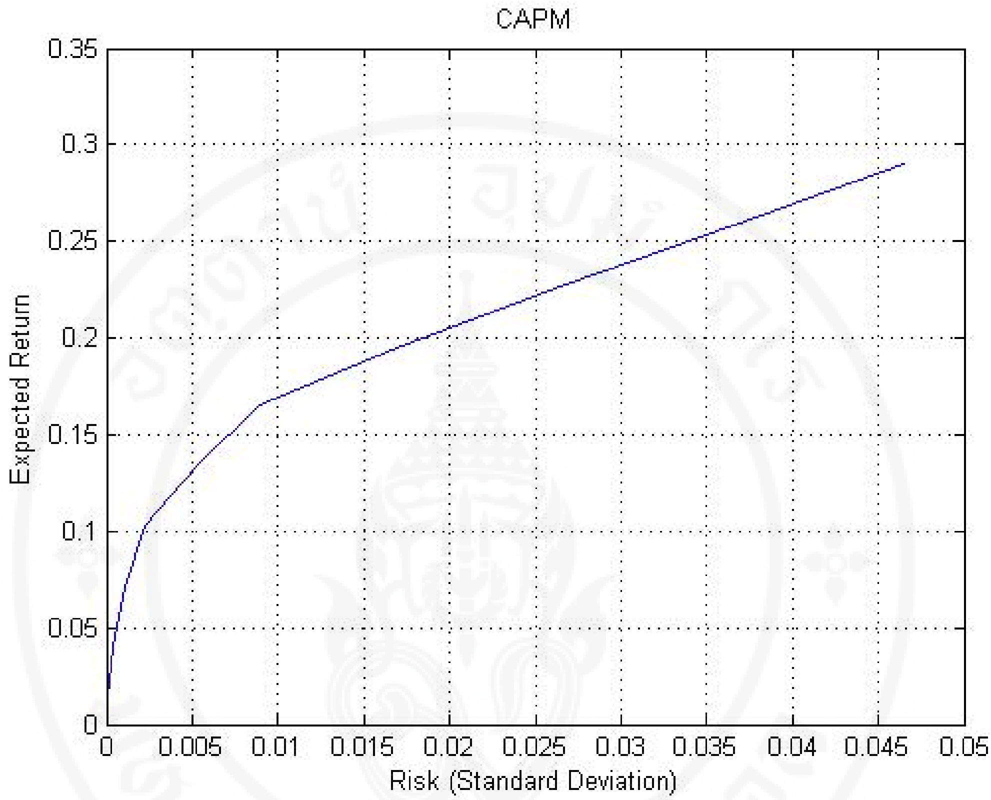


Figure A1.18 Optimal Portfolio 3 years historical data(Dec 2006 - Dec 2007) with Fama-French 3 Factors Model Method

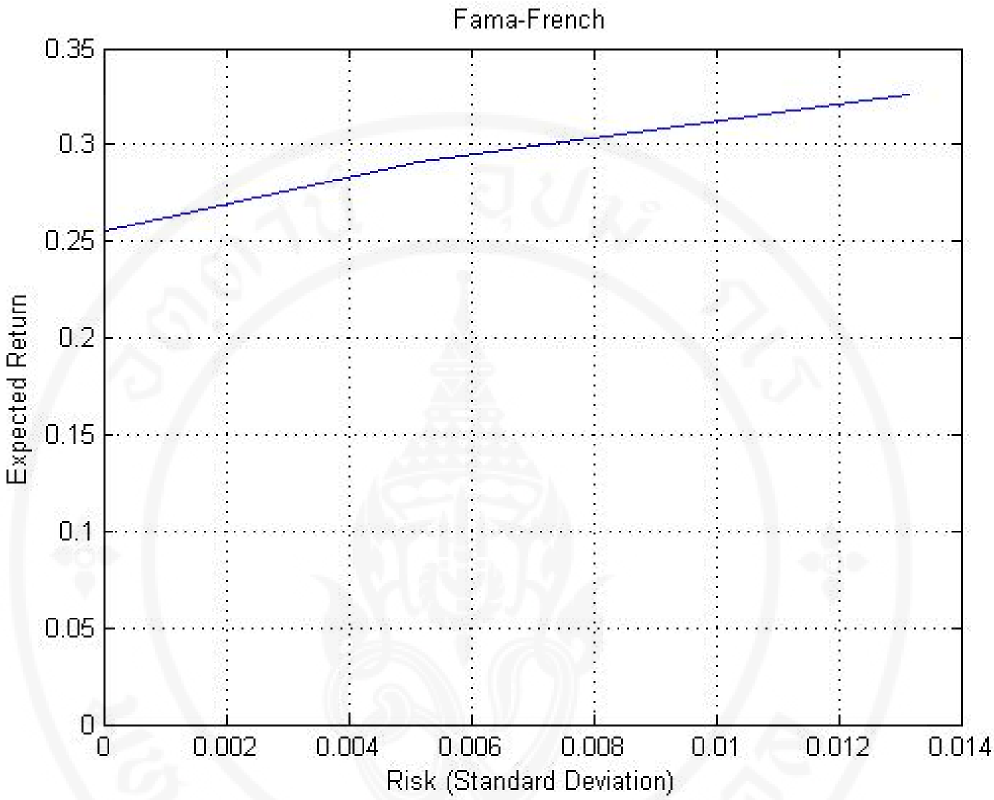


Figure A1.19 Optimal Portfolio 5 years historical data(Dec 1997 - Dec 2002) with Markowitz Method

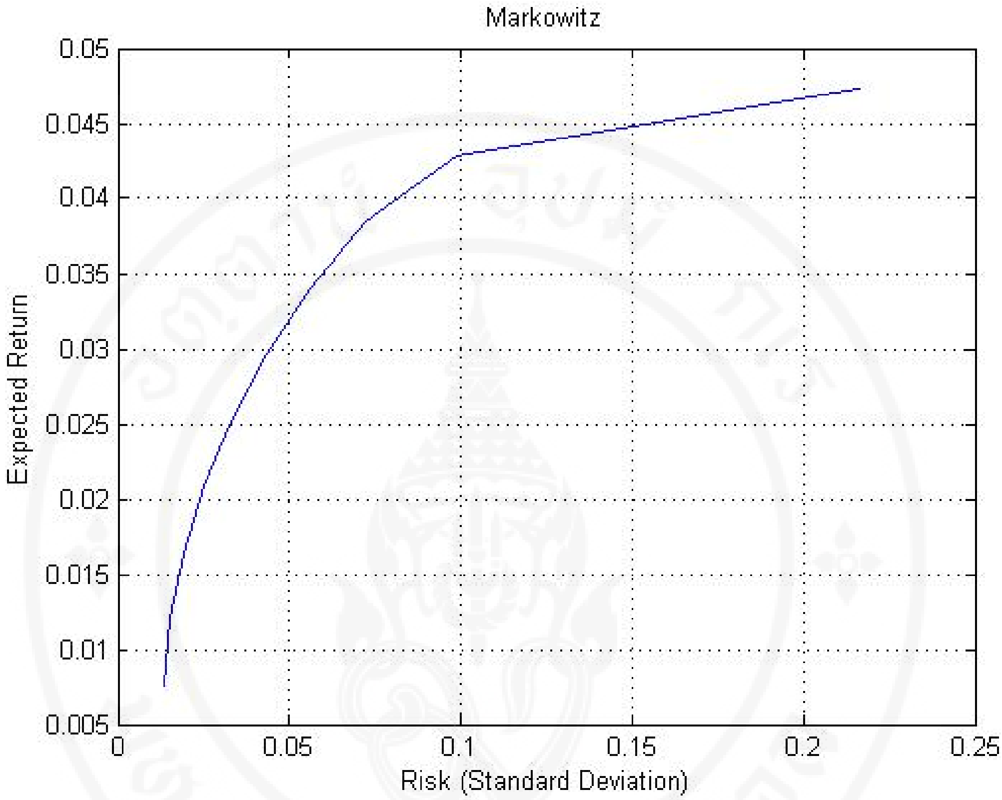


Figure A1.20 Optimal Portfolio 5 years historical data(Dec 1997 - Dec 2002) with CAPM Method

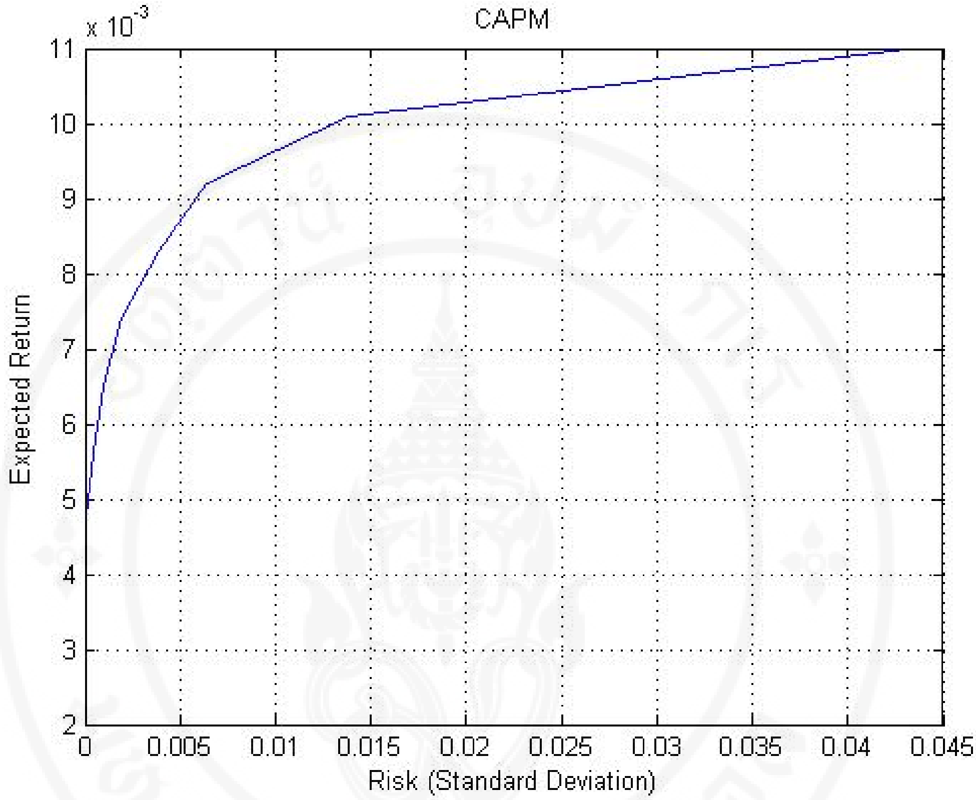


Figure A1.21 Optimal Portfolio 5 years historical data(Dec 1997 - Dec 2002) with Fama-French 3 Factors Model Method

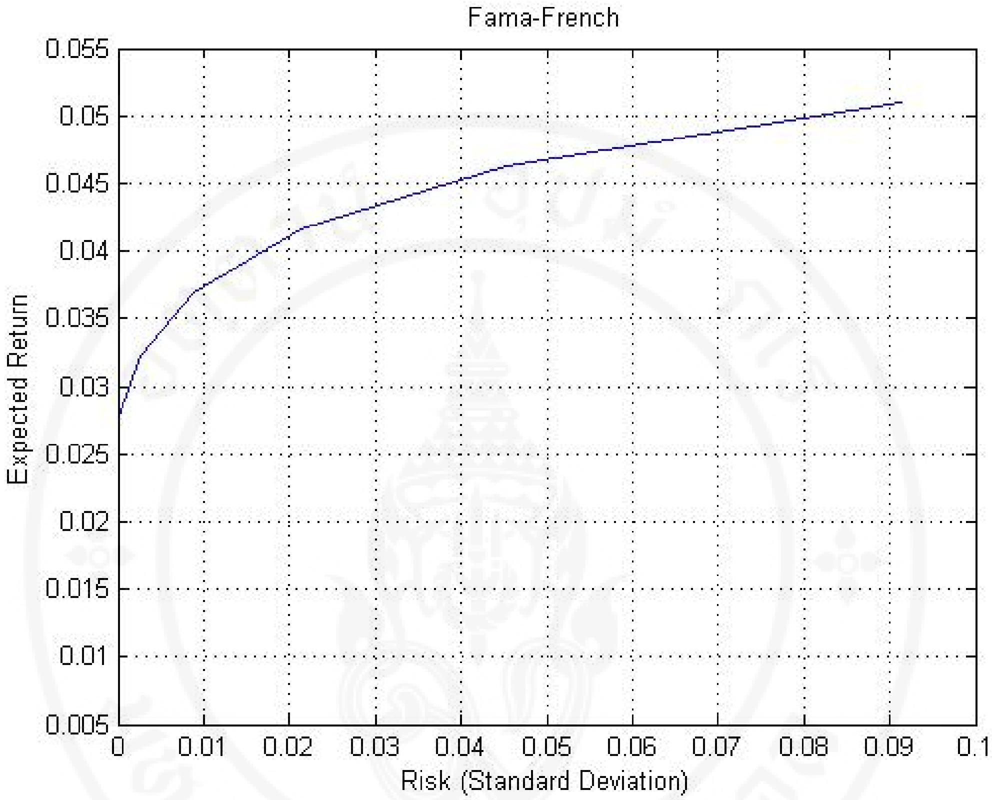


Figure A1.22 Optimal Portfolio 5 years historical data(Dec 1998 - Dec 2003) with Markowitz Method

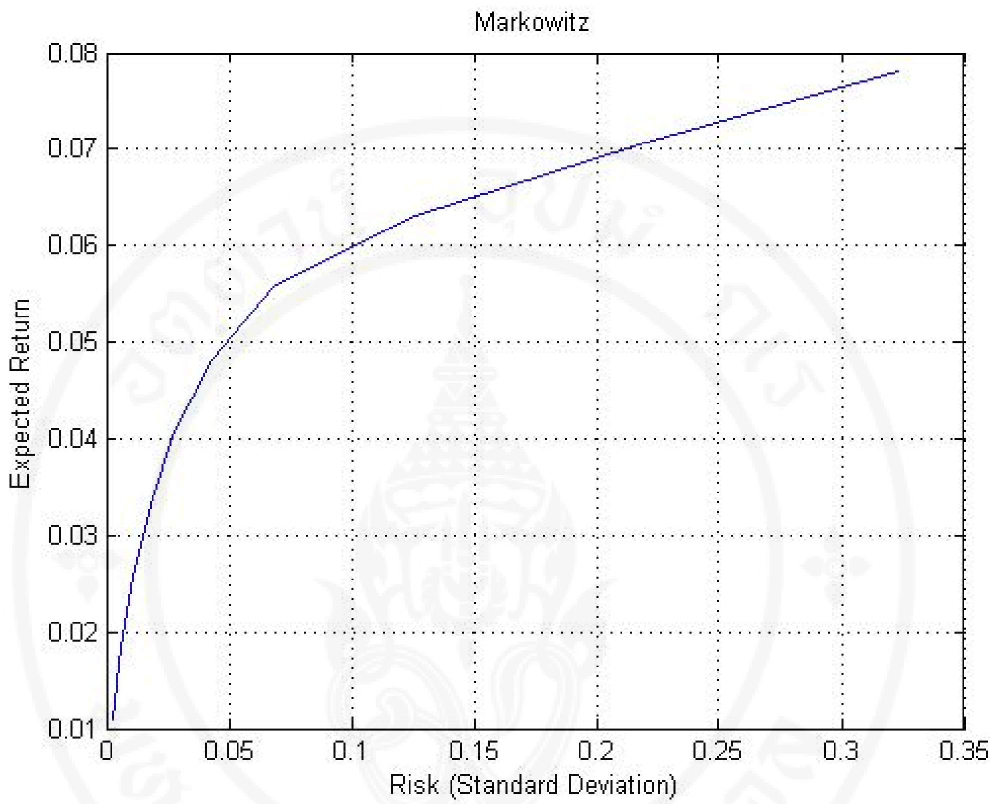


Figure A1.23 Optimal Portfolio 5 years historical data(Dec 1998 - Dec 2003) with CAPM Method

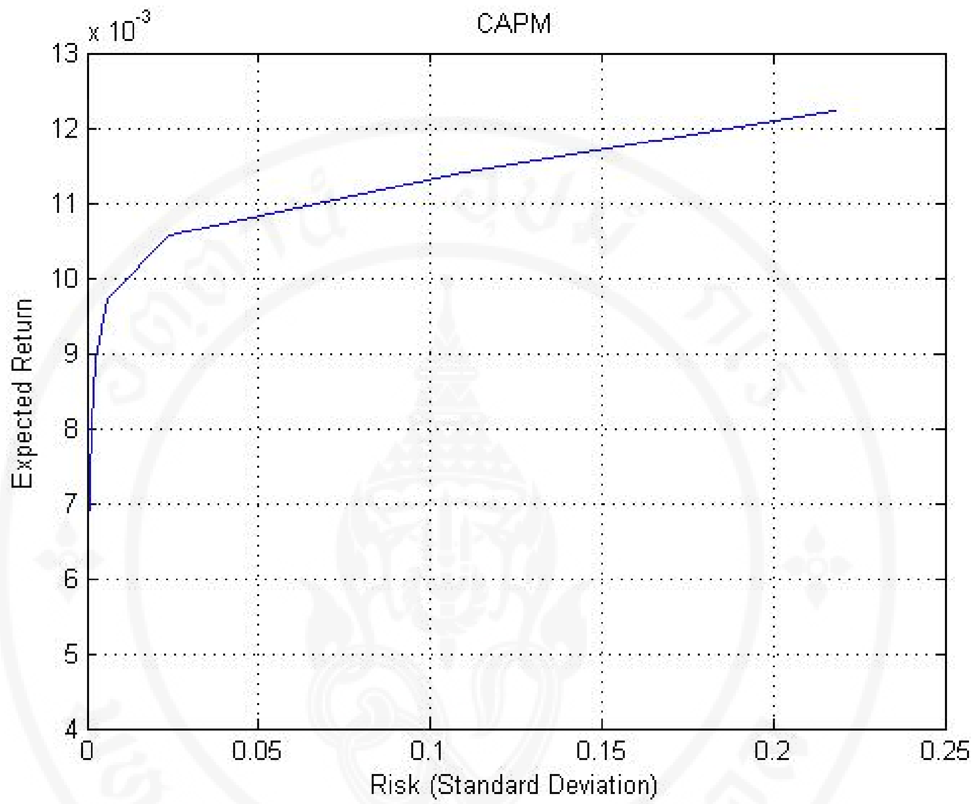


Figure A1.24 Optimal Portfolio 5 years historical data(Dec 1998 - Dec 2003) with Fama-French 3 Factors Model Method

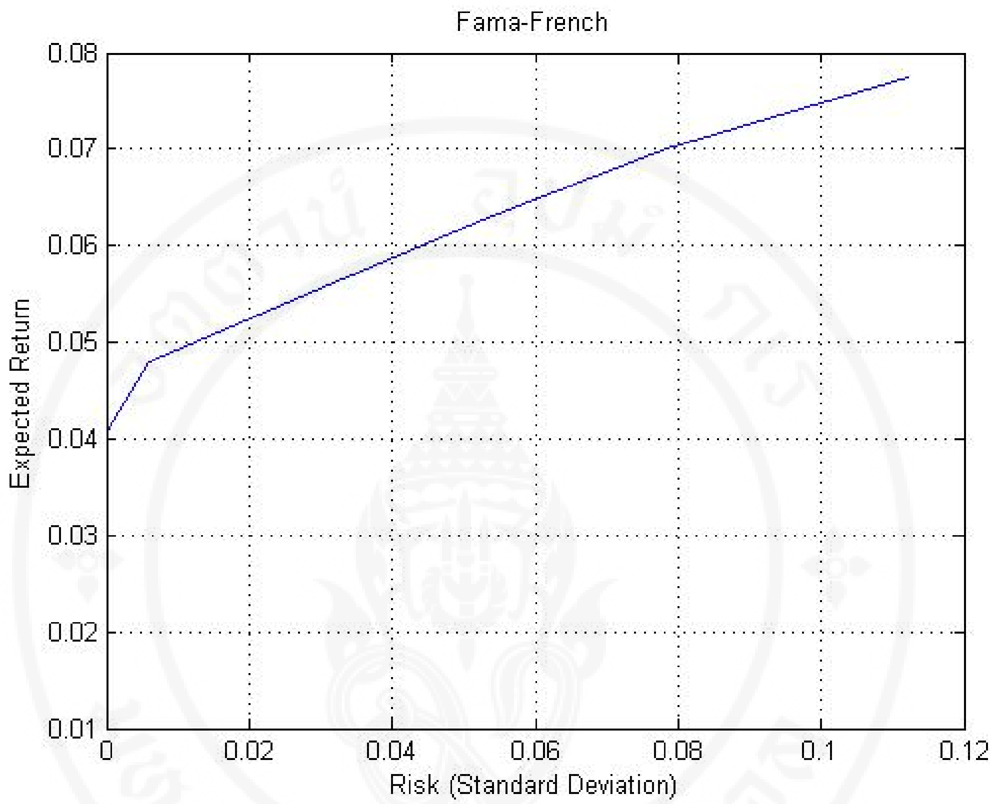


Figure A1.25 Optimal Portfolio 5 years historical data(Dec 1999 - Dec 2004) with Markowitz Method

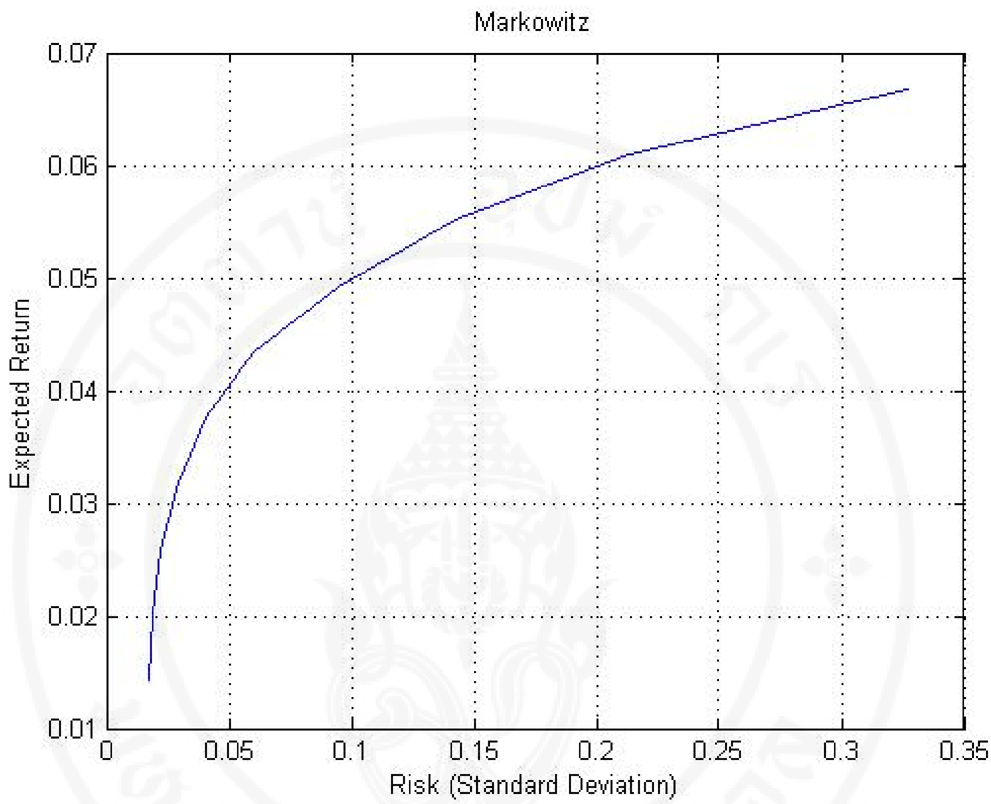


Figure A1.26 Optimal Portfolio 5 years historical data(Dec 1999 - Dec 2004) with CAPM Method

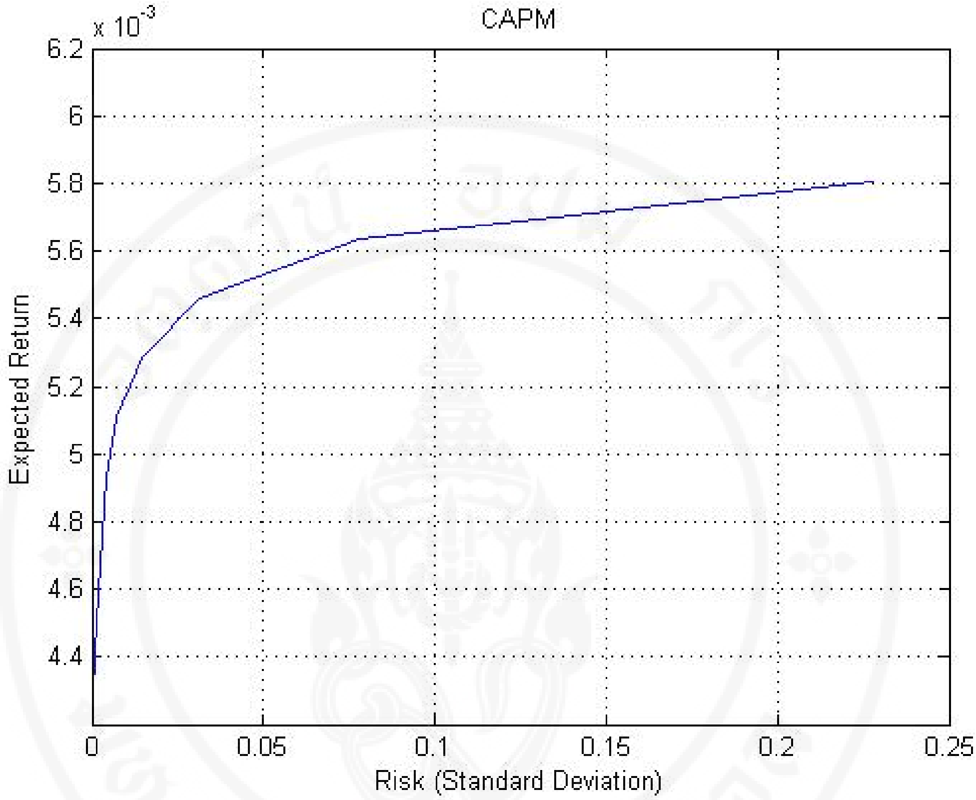


Figure A1.27 Optimal Portfolio 5 years historical data(Dec 1999 - Dec 2004) with Fama-French 3 Factors Model Method

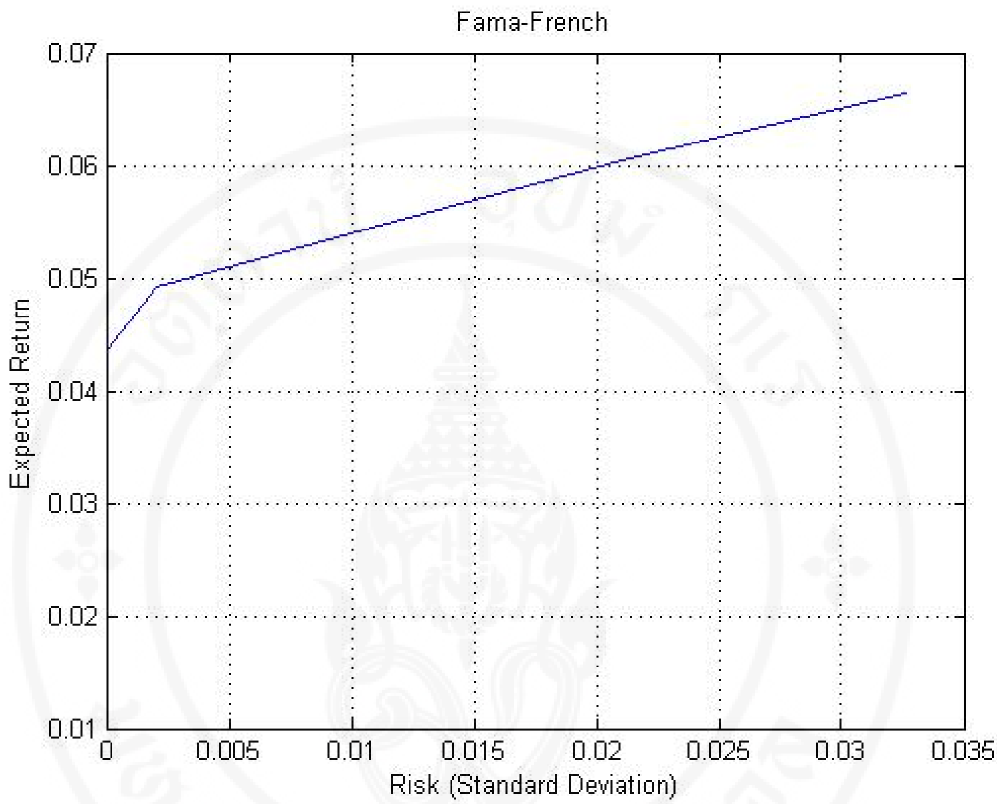


Figure A1.28 Optimal Portfolio 5 years historical data(Dec 2000 - Dec 2005) with Markowitz Method

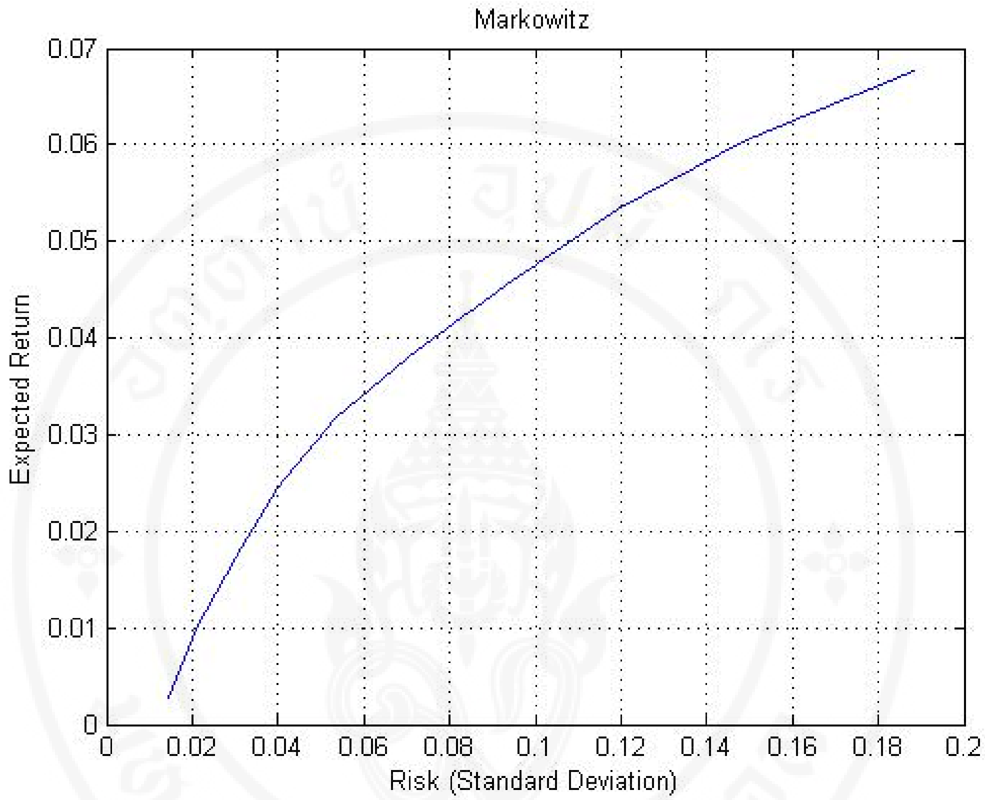


Figure A1.29 Optimal Portfolio 5 years historical data(Dec 2000 - Dec 2005) with CAPM Method

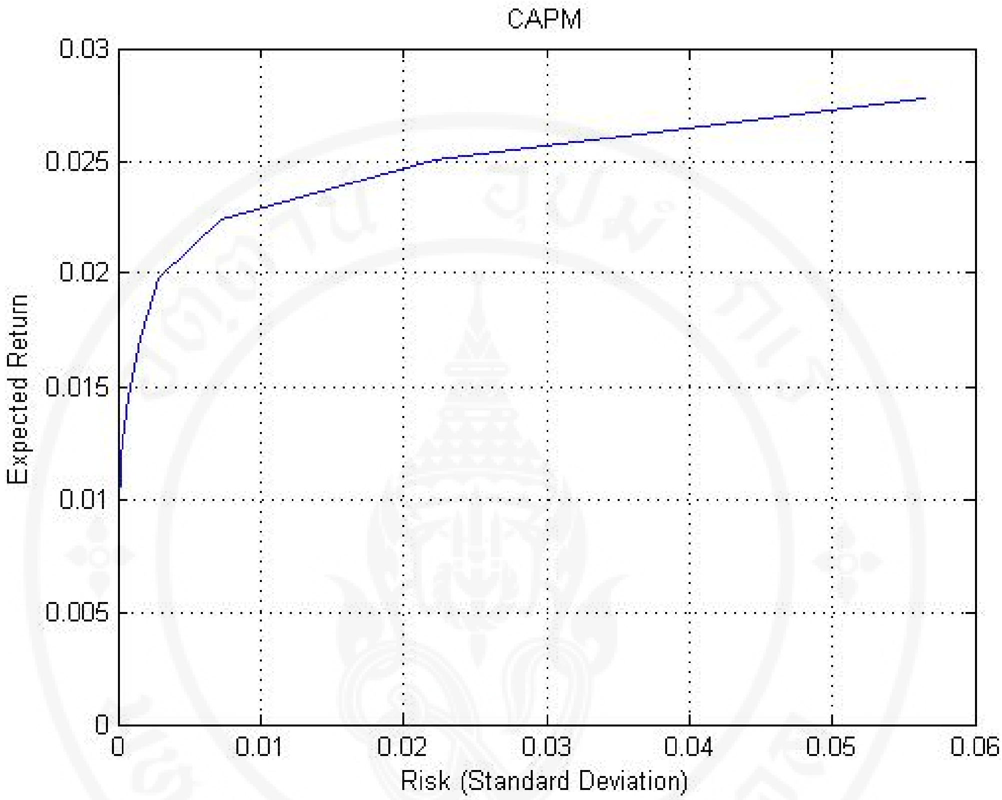


Figure A1.30 Optimal Portfolio 5 years historical data(Dec 2000 - Dec 2005) with Fama-French 3 Factors Model Method

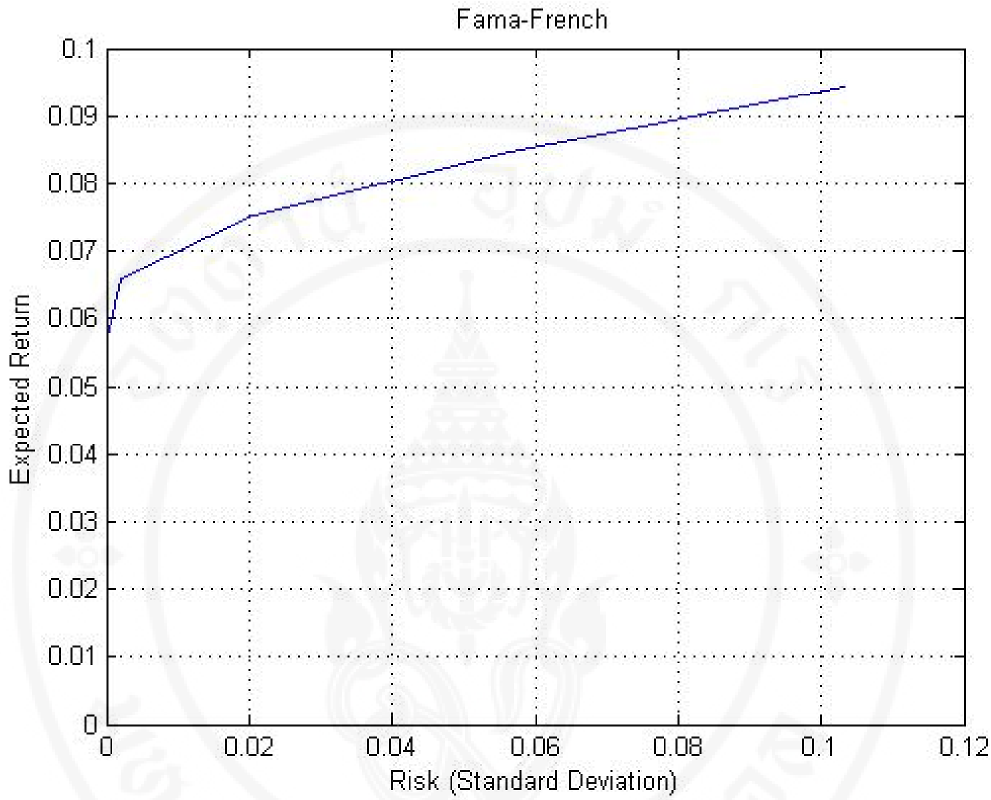


Figure A1.31 Optimal Portfolio 5 years historical data(Dec 2001 - Dec 2006) with Markowitz Method

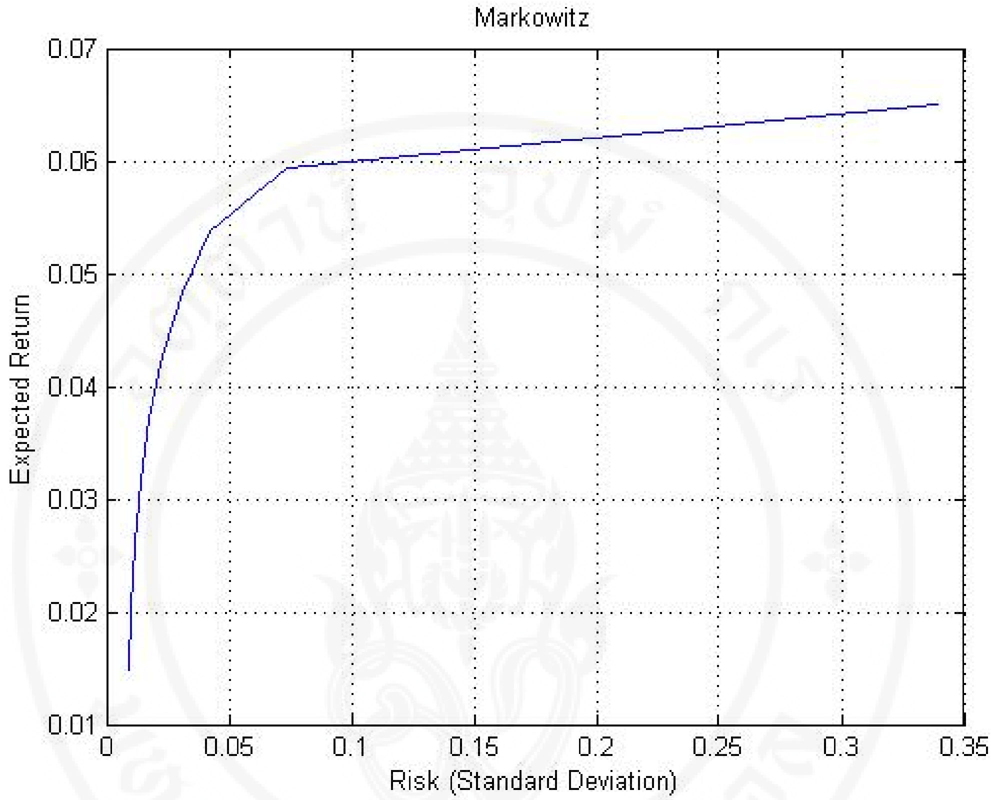


Figure A1.32 Optimal Portfolio 5 years historical data(Dec 2001 - Dec 2006) with CAPM Method

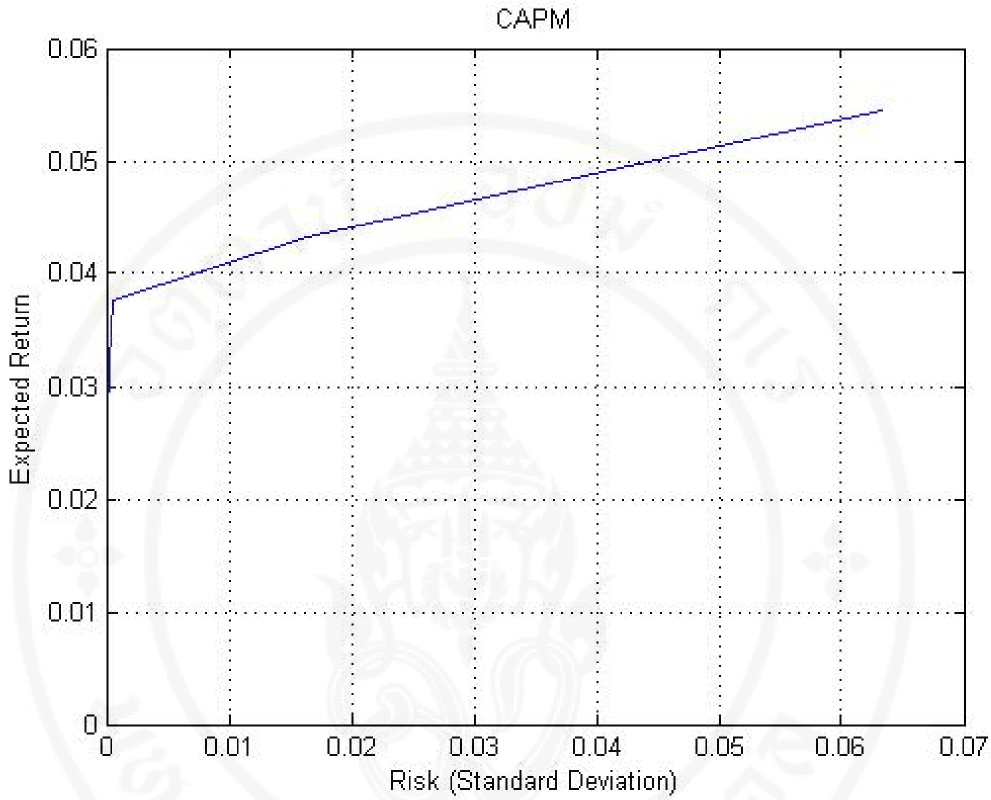


Figure A1.33 Optimal Portfolio 5 years historical data(Dec 2001 - Dec 2006) with Fama-French 3 Factors Model Method

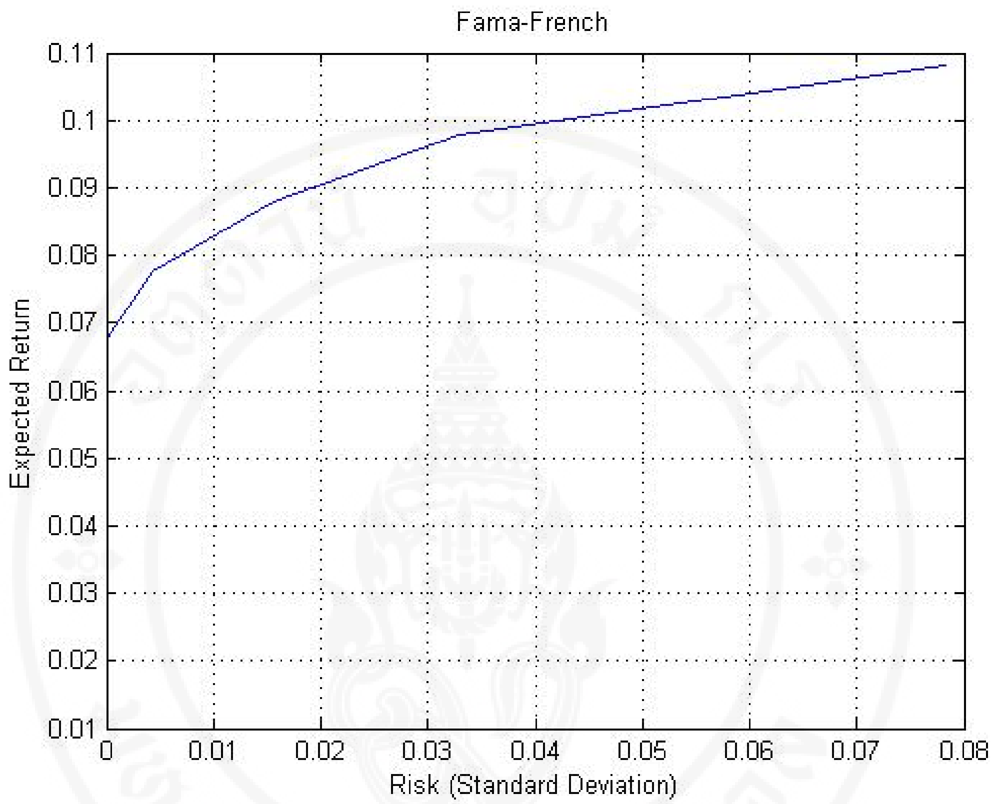


Figure A1.34 Optimal Portfolio 5 years historical data(Dec 2002 - Dec 2007) with Markowitz Method

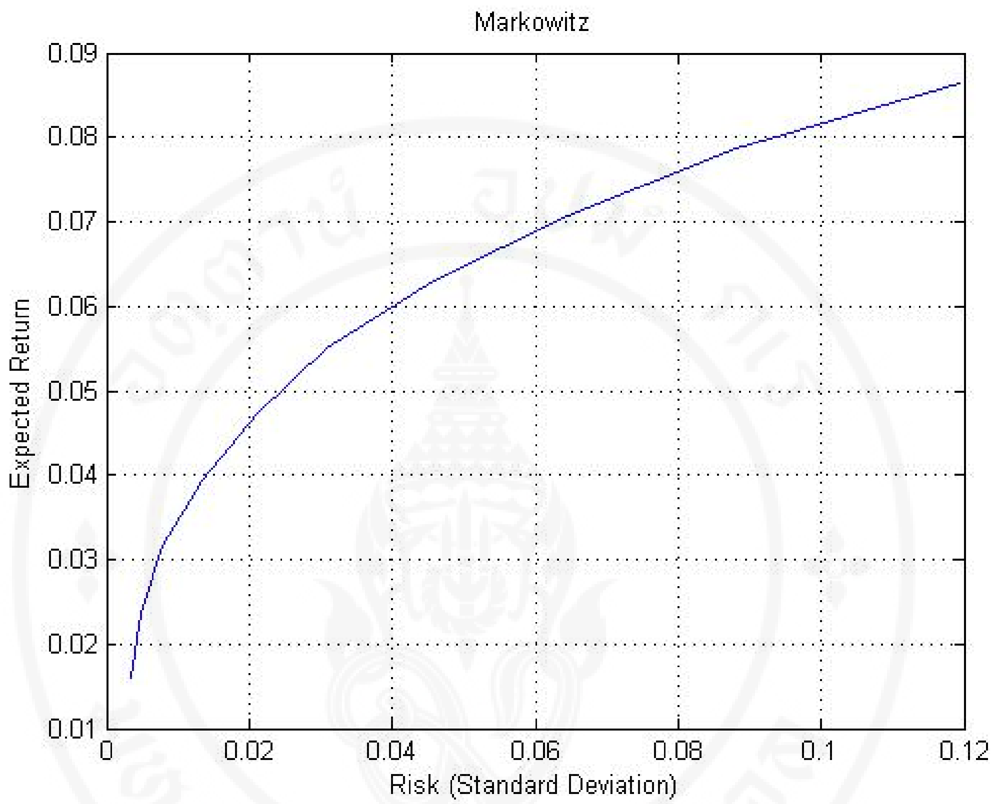
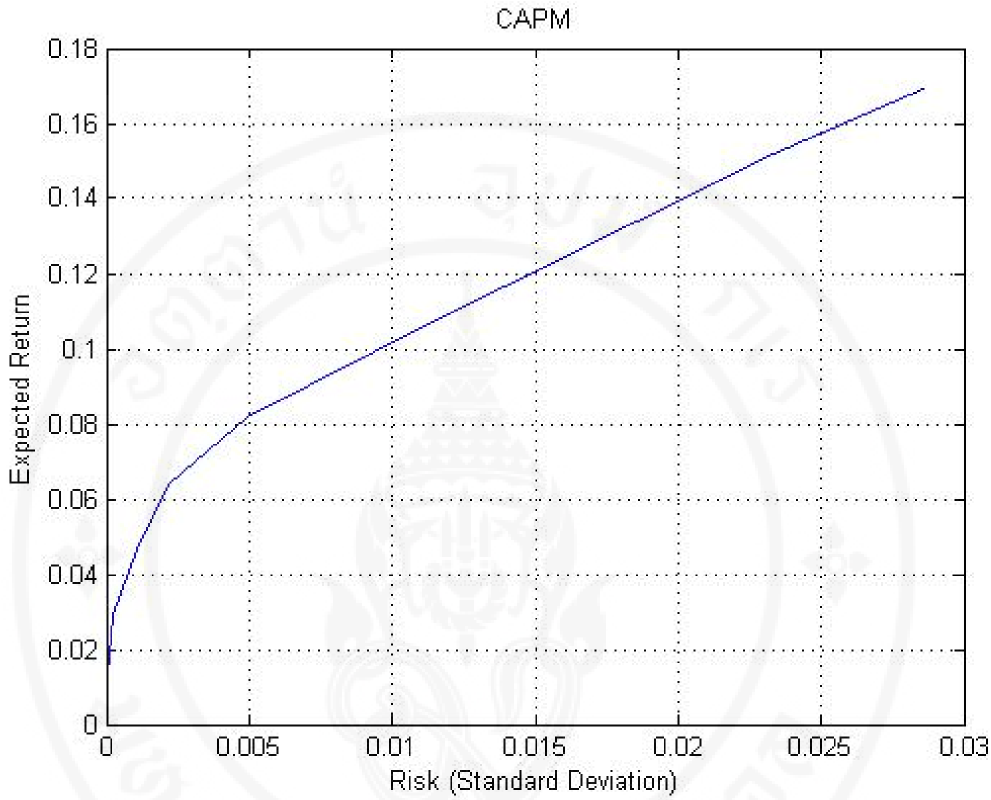
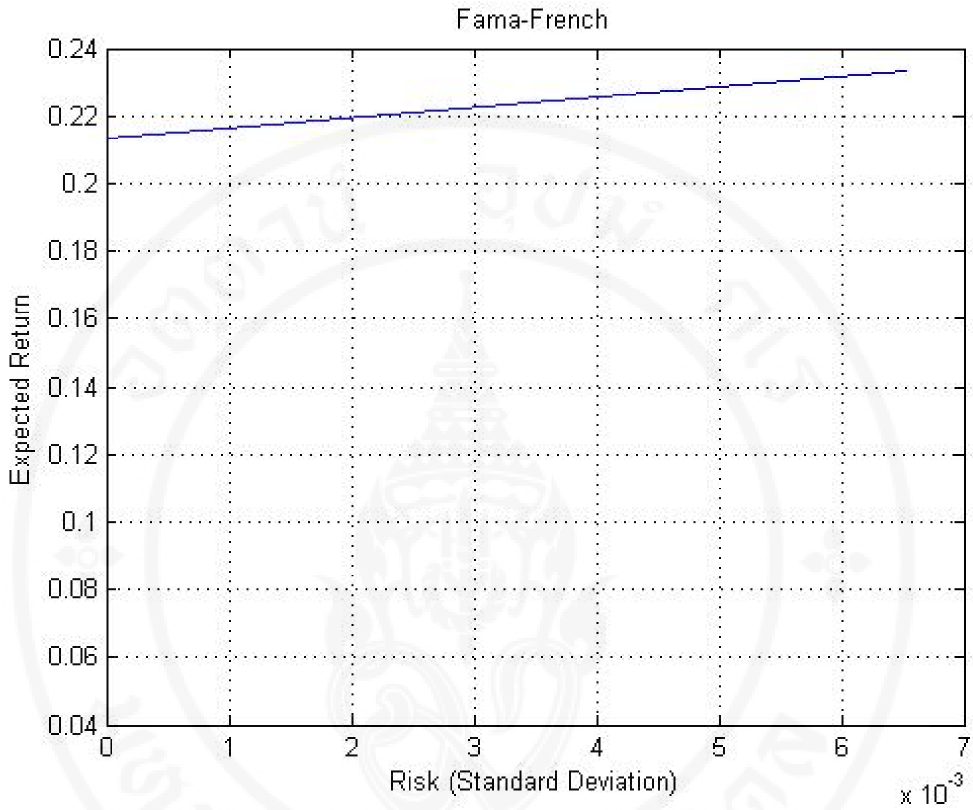


Figure A1.35 Optimal Portfolio 5 years historical data(Dec 2002 - Dec 2007) with CAPM Method



FigureA1.36 Optimal Portfolio 5 years historical data(Dec 2002 - Dec 2007) with Fama-French 3 Factors Model Method



BIOGRAPHY

NAME	Kanis Charntaweekhun
DATE OF BIRTH	15 April 1985
PLACE OF BIRTH	Bangkok, Thailand
INSTITUTIONS ATTENDED	King Mongkut ‘s Institute of Technology Ladkrabang, 2004 - 2007 Bachelor of Engineering (Computer) Mahidol University, 2008-2010 Master of Business Administration (Business Modeling and Analysis)
HOME ADDRESS	41/8 Moo3 Soi Jariphibune Phibunesongkram Road Nonthaburi 11000 Tel : 02-526-1061 Email : pakkardkaw@hotmail.com
EMPLOYMENT ADDRESS	ExxonMobil LTD Tel : 02-262-4640 Email : th-kcw@exxonmobil.com
PUBLICATION / PRESENTATION	Computer Language for beginner using Flochart International Symposium on Communications and Information Technologies(ISCIT) 2006 Portfolio Performance Incorporating Three Factors Model National Conference on Applied Arts 2010