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# The Capital Asset Pricing Model: A New Empirical Investigation

*Ali Zarifhonarvar* \*

## **Abstract**

In financial economics, numerous theoretical models explain the relationship between investment risk and return in the capital market, one of the most common being the Capital Asset Pricing Model (CAPM). After reviewing the literature in this area, this study discusses the theoretical background of the CAPM model. After explaining the relationship between systematic corporate risk in different industries, the hypotheses for a positive linear correlation between stock returns and systematic risk and the relation of these coefficients to the CAPM model predictions are tested. Thus, after data sampling to obtain the monthly rate of return of stocks in the Tehran Stock Exchange, the monthly rate of return of the market portfolio and the return on risk-free investment are obtained from April 2008 to March 2013. Finally, it will be shown that the systematic risk variable and its square are also crucial to explaining stock return fluctuations. A nonlinear quadratic correlation is confirmed between the rate of return and systematic risk in the stock data of companies sampled from the obtained sample of the Tehran Stock Exchange.

**Keywords:** CAPM, Beta, Stock Market, Premium, Risk

**JEL:** G10, G11, G12

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## 1 Introduction

The numerous securities traded daily on the stock market are priced based on the interaction of different variables, each affecting the price differently and with a different intensity. Many studies have examined the patterns or mechanisms of this market. In the financial economics literature, risk and return are the two main pillars of decision-making for any investment. Each person's decision is based on choosing high-return and low-risk assets. Investors should choose their optimal portfolio by assessing their sensitivity to each asset's risk and return. Fundamentally, financial economics researchers have always focused on considering the risk factor, the relationship between risk and expected return, and presenting a model to show this relationship.

The capital asset pricing model<sup>1</sup> is one of the most important models for expressing the correlation between expected risk and return. Many modern financial economics theories are based on this classic model. The capital asset pricing model describes the relationship between risk and expected return. In the central point of this model, there is a trade-off between risk and expected return. Such models are fundamentally used to obtain an efficient portfolio.

This study aims to validate this model in the Tehran Stock Exchange and whether this model, which is based on different theoretical and empirical situations, is consistent with the events of the Iranian capital market.

## 2 Literature Review

Since the introduction of CAPM, there has been a great number of theoretical and empirical research on the main model and its extensions.

Numerous studies have been published in the financial economics literature about this model, both theoretically and empirically. Following the simple Sharpe-Lintner model published in 1964 and 1965, many similar models were proposed. Table 1 shows the complete list of CAPM-related models.

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<sup>1</sup> CAPM

Tab. 1: Capital Asset Pricing Model and its Extensions

<b>Model</b>	<b>Author(s)</b>
<b>Mean-Variance Algorithm</b>	Markowitz (1952)
<b>Sharpe-Lintner CAPM</b>	Sharpe (1964); Lintner (1965); Mossin (1966)
<b>Black Zero-beta CAPM</b>	Black et al. (1972)
<b>CAPM with Human Capital</b>	Mayers (1973)
<b>CAPM with Consumption Goods</b>	Breeden (1979)
<b>International CAPM</b>	Solnik (1974); Adler and Dumas (1983)
<b>Arbitrage Pricing Theory</b>	Ross (1976)
<b>Fama-French Three Factor Model</b>	Fama and French (1993)
<b>Partial Variance Approach</b>	Hogan and Warren (1974); Bawa and Lindenberg (1977); Harlow and Rao (1989)
<b>The Three Moment CAPM</b>	Rubinstein (1973); Kraus and Litzenberger (1976)
<b>The Four Moment CAPM</b>	Fang and Lai (1997)
<b>The Intertemporal CAPM</b>	Merton (1973)
<b>The Consumption CAPM</b>	Breeden (1979)
<b>Production Based CAPM</b>	Lucas Jr (1978); Brock (1982)
<b>Investment-Based CAPM</b>	Cochrane (1991)
<b>Liquidity Based CAPM</b>	Acharya and Pedersen (2005)
<b>Conditional CAPM</b>	Jagannathan and Wang (1996)

Initial studies on the Sharpe-Lintner model made predictions about the intercept and slope of the correlation between expected return and market beta. The problem with such research was that the inaccurate beta estimates for individual assets created measurement errors. Moreover, the regression residual as a source of changes and its positive correlation caused a downward estimation bias in the cross-sectional regression slope. Researchers proposed various methods to solve this problem. For example, Black et al. (1972) used stock portfolios. The beta of these diversified portfolios was much more accurate. Then, Fama and MacBeth (1973) suggested that instead of a cross-sectional regression for average monthly return and beta, a cross-sectional month-to-month regression for the monthly return on beta was necessary, which mitigates the problem of residual correlation.

Another approach was first proposed by Jensen (1968), who stated that the Sharpe-Lintner version used to express the relationship between expected return and beta could be tested by the time-series method.

The empirical studies in different countries, such as Turkey, the United States, Finland, Sweden, Uganda, India, Italy, and Greece, to examine the gap between theory and evidence have all found that the simple CAPM model cannot explain the correct relationship between risk and return. Therefore, ac-

According to researchers such as Fama and French (1993), the empirical studies around this model are so poor as to invalidate it practically. Although problems with empirical research may reflect a weakness, in theory, they could also arise from the absence of valid tests.

Generally, this model has many opponents and supporters. Some, like McGoun (1993), consider it a big failure, whereas others, like Levy (2010), argue that it is still valid and adequate. However, most researchers believe that one should consider when and in what conditions it should be used for decision-making.

## 2.1 Theoretical Background

Due to the extensive applications of CAPM in financial research, it is still considered a standard model in the literature. This model was developed in the mid-1960s to express the relationship between stock market risk and return. CAPM, which is based on the theoretical works of Markowitz (1952) such as modern portfolio theory, mean-variance, and diversification, was separately explained by Sharpe (1964), ?, and Mossin (1966).

According to this model, the risk of each asset is determined based on the dependence of its return on the market portfolio's return, and the relationship between risk and expected return will be linear and direct. So that:

$$E(R_i) = R_f + [E(R_m) - R_f]\beta_i$$

where  $E(R_i)$  is the expected return of asset  $i$ ,  $R_f$  is the risk-free return,  $E(R_m)$  is the expected market return, and  $\beta_i$  is the systematic risk index.

This model divides risk into two parts, namely systematic and unsystematic. The systematic risk or beta ( $\beta_i$ ) is how a stock functions relative to the market stock, such that the expected return of the asset depends on it. However, unsystematic risk is related to the specific conditions of each share. This model has taken shape under the following conditions (Bodie et al., 2013).

- There are many investors with an initial wealth that is a small fraction of the total wealth of investors. That is, people are price takers, and the stock price will not change with the trade of individuals. This is the conventional perfect competition assumption in microeconomics.
- All investors have planned for the same specific period.
- Investments are made only among tradable financial assets such as stocks, bonds, and a risk-free asset that can be lent and borrowed. This assumption rejects investment in non-tradable assets, such as education.
- Investors pay no tax on returns, and there are no transaction costs such as commission fees.
- All investors are mean-variance optimizers; that is, they all use Markowitz's portfolio selection theory.

- All investors are rational and risk-averse.
- All investors analyze their choices from a standard economic point of view. That is, they all have homogeneous expectations.

The basic CAPM was presented with three testable hypotheses (Fama and French, 1993).

1. There is a linear correlation between the expected return and systematic risk or beta, and no other variable other than beta affects the return of securities.
2. Only the risk caused by beta is positive.
3. The expected return on assets uncorrelated with the market is equal to the risk-free rate of return.

### 3 Empirical Questions

This study raises four questions:

#### Question 1:

Is the beta distribution in each industry significantly different from the other industry in the Stock Market?

$H_0$ : The beta confidence interval (systematic risk) of two industries out of the 9 industries selected in the sample overlap.  $H_1$ : The beta confidence intervals (systematic risk) of at least two specific industries out of the 9 industries selected in the sample are separate.

#### Question 2:

According to the CAPM model, is there a simple and positive linear correlation between the return and systematic risk of the sample companies in the Stock Market?

$H_0$ : The simple linear regression coefficients of stock return on systematic risk (beta) are not significant.  $H_1$ : The simple linear regression coefficients of stock return on systematic risk (beta) are significant.

#### Question 3:

If the answer to the second question is affirmative, is the systematic risk coefficient equal to the market risk predicted by CAPM? Does the intercept of the simple linear regression according to the model's prediction equal the risk-free return rate?

$H_0$ : The slope of the simple linear regression of the stock return on systematic risk (beta) is not significantly different from market risk, and its intercept is not significantly different from the risk-free rate of return.  $H_1$ : The slope of

the simple linear regression of the stock return on systematic risk (beta) is significantly different from market risk. In other words, the intercept of this regression is significantly different from the risk-free rate of return.

#### Question 4:

Assuming a negative answer to the second question, is there a non-linear correlation between the return and systematic risk of sample companies in the Stock Market? Does a non-linear correlation better explain stock return volatility in terms of systematic risk?

$H_0$ : The multivariate and non-linear regression coefficients of stock return on systematic risk (beta) are not significant.  $H_1$ : The multivariate and non-linear regression coefficients of stock return on systematic risk (beta) are significant.

### 3.1 Date and Method

This study used the data available on the official Tehran Stock Exchange website, the Securities and Exchange Management Company website, and Rahavard-e-Novin software to obtain the time series of securities prices, dividends, the time and amount of capital raised by companies, and more. This study covered all companies listed on the Tehran Stock Exchange from April 2008 to March 2013 (60 consecutive months). The sampling method initially started with the classification of 9 different industries. To further validate the results, the stocks of companies that were traded relatively regularly during these five years were selected. First, 10 out of 90 companies were selected in each of the 9 industries. However, given the lack of data and relatively long breaks in trading certain stocks, the number of samples was reduced to 52. Table 2 shows the selected companies in the sample during the research period.

Tab. 2: Companies in the Sample Categorized by the Industry

Industry	Number of Companies
Real Estate	9
Finance and Banking	4
Automobiles	5
Cement	5
Metals	5
Machinery	3
Chemicals	3
Food and Beverages	8
Pharmaceutical	10
<b>Total</b>	<b>52</b>

First, the monthly time series data were obtained from the daily data; based on companies' dividends and raised capital, the adjusted prices and the monthly

returns of companies were calculated. This study considered the market representative portfolio equivalent to the Tehran stock market portfolio for obtaining the total price index. Hence, the monthly time series of market returns were obtained from the total index.

One of the assumptions of CAPM is that the variance index of the time series of returns is used as a measure of investment risk. Therefore, the more symmetrical and closer to the normal distribution, the return of companies and market share, the greater the consistency with the assumptions of CAPM. The appendix presents some data related to the distribution of the return of companies. The normal distribution assumption of monthly returns was rejected significantly for about 85% of companies.

## 4 Results

### 4.1 Beta Calculation

To answer the first question, the beta of companies listed on the stock exchange should be estimated. The beta of each firm's stock is obtained using the following equation:

$$\beta_i = \frac{Cov(r_{jt}, r_{mt})}{Var(r_{mt})}$$

The numerator is the covariance between the monthly return of company  $i$  and the monthly market return, and the denominator is the variance of the market's monthly return over 60 months.

Figure 1 shows the histogram of the 52 companies' beta in the sample next to the market beta (equal to 1) and the beta of a portfolio comprised of the weighted average of the top 50 companies in the Tehran Stock Exchange. The mean of betas is 0.44, with a standard deviation of 0.43. Furthermore, the minimum and maximum betas are respectively -0.28 and 1.73. As we know, a greater beta means a riskier stock and betas greater than one correspond to aggressive and risky investments, whereas betas smaller than one correspond to defensive investments. Beta turns negative when the stock's return moves against the trend of the market's average return (portfolio representative of the market).



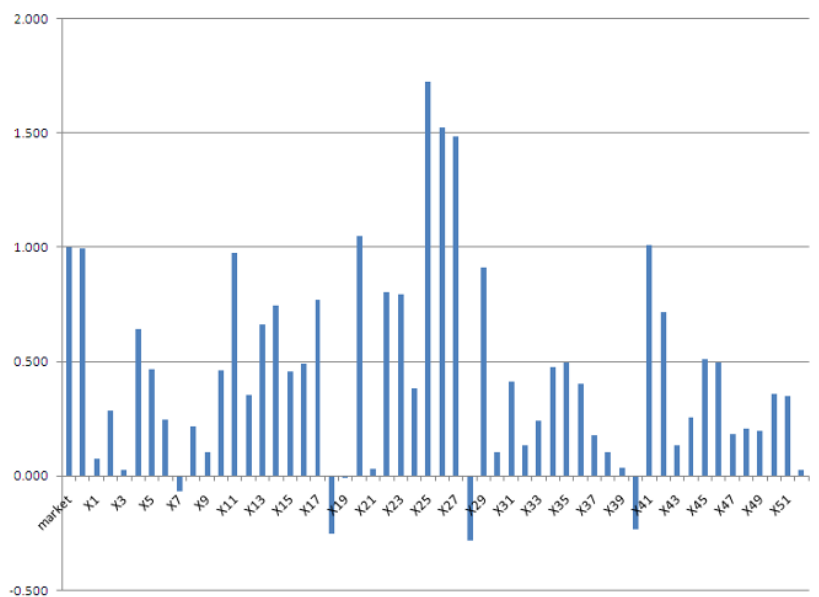


Fig. 1: Beta Coefficient for 52 Companies

Table 3 shows the summary statistics of beta by industry. The beta confidence interval of the "Cement" industry is significantly (at 5%  $\alpha$ ) different from the beta confidence interval of the "real estate," "chemicals," and "Pharmaceutical" industries. The beta confidence intervals of the remaining industry pairs all overlap and are not significantly different.

Tab. 3: Statistical Descriptions of Beta by Industry

Sector	Average of Beta	SD	95% CI
Real Estate	0.222	0.223	[0.076,0.368]
Finance and Banking	0.518	0.348	[0.291,0.746]
Automobiles	0.454	0.441	[0.166,0.741]
Cement	0.865	0.641	[0.446,1.284]
Metals	0.711	0.725	[0.236,1.184]
Machinery	0.372	0.251	[0.208,0.536]
Chemicals	0.203	0.233	[0.051,0.355]
Food and Beverages	0.315	0.381	[0.067,0.564]
Pharmaceutical	0.299	0.136	[0.211,0.389]

## 4.2 Linear Relationship Between Stock Price and Systematic Risk

This section will answer the second research question. The problem with calculating the beta is the lack of accurate information about its measurement error.

The beta for a company is estimated from only "one" time series of rates of return, making measurement errors likely to happen. Thus, if the slope of the return regression of a company on its systematic error is found, it could lead to bias in calculating the regression coefficient.

Instead of estimating the beta of a single company's stock, Black suggests estimating the beta of a portfolio of the stocks of several companies. By forming a portfolio, the lower and higher estimates of the betas of corporate stocks largely cancel each other out (Black et al., 1972). Black did the same and ran the regression on data from 10 selected portfolios. The portfolio was created in two ways to examine the low (similar to Black) and high data volume results. Figure 2 shows the bar chart of the sorted beta of stocks from small to large.

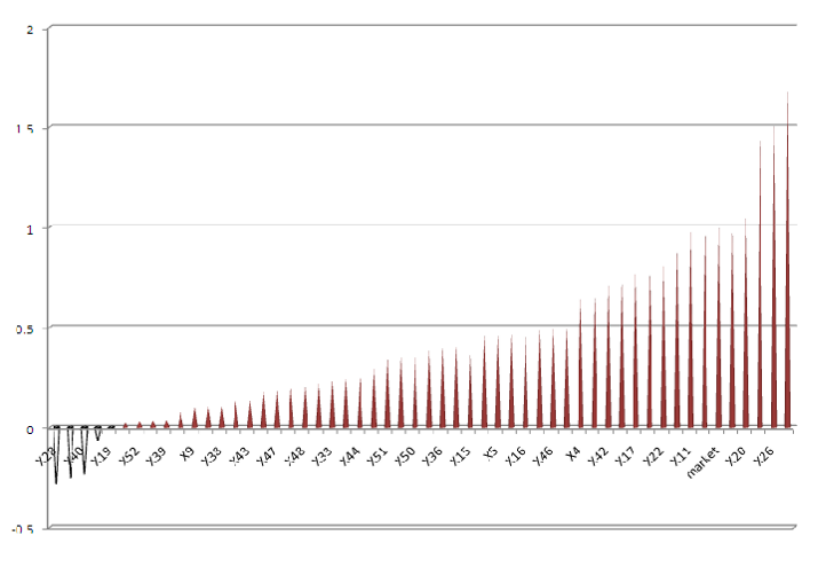


Fig. 2: Sorted Beta Coefficient for 52 Companies

In the first case, 52 companies were sorted in ascending order of their beta, and every four companies were placed in one portfolio from bottom to top. Thus, 13 portfolios were obtained. The average rate of return and beta of each portfolio was calculated separately. The betas of the portfolios are expected to be calculated automatically in ascending order. Figure 3 shows the same.

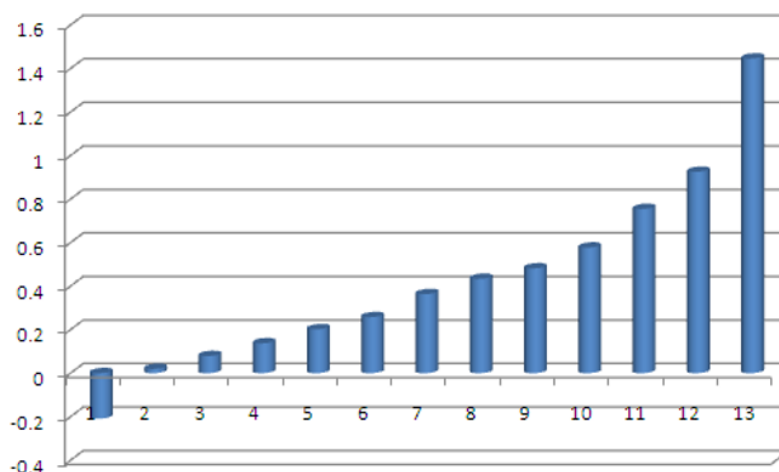


Fig. 3: Beta Coefficient for Portfolios

As shown in the appendix, the distribution of returns of 6 out of 13 portfolios are close to the normal distribution. Black attributes this approach to portfolio formation to preserving the range of beta changes Black et al. (1972). Suppose the companies are divided in the portfolios in no particular order. In that case, the estimated betas of companies could be distributed on a limited spectrum (e.g., 0.2 to 0.7), increasing the standard deviation of the regression coefficients and reducing the accuracy of calculations.

The drawback to Black's portfolio formation method is the significant reduction in the number of observations, which is another factor reducing the accuracy of coefficient estimation. To this end, an alternative method of portfolio formation was considered. Here, 120 portfolios with sizes of 4, 5, 6, 7, 8, 10, and 15 were considered with different combinations of portfolio formation. Meanwhile, there was an attempt to form portfolios so that increasing the number of portfolios did not decrease the range of the resulting betas. Figure 4 shows the beta distribution of 120 portfolios in ascending order. These 120 portfolios (Figure 4) have obtained a good coverage of the beta variation range of single companies (Figure 2).

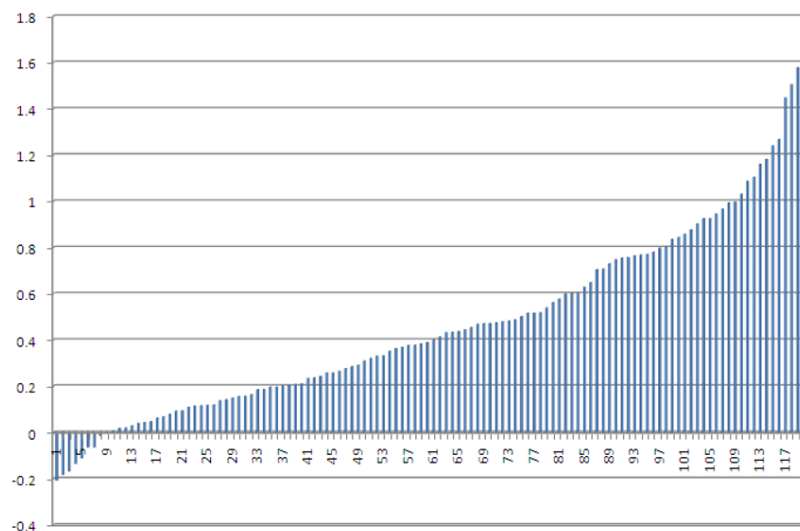


Fig. 4: 120 Beta Coefficient for 120 Portfolios

Consider the following linear regression model:

$$\overline{r_{pt} - r_{ft}} = \alpha_0 + \alpha_1 \beta_p$$

The variable on the left is the mean difference of the monthly return of portfolio  $p$  from the risk-free return. Risk-free return is based on the one-year interest rate of banks approved by the Central Bank from 2008 to 2012 after conversion to monthly interest. The  $\beta_p$  variable is the beta of each portfolio. CAPM predicts that in addition to the  $\alpha_0$  and  $\alpha_1$  coefficients becoming significant, they should not significantly deviate from zero and be different from the real value of  $r_{pt} - r_{ft}$  (the mean difference of the monthly market return deducted from the risk-free return). The above linear and simple regression model is now estimated for the 13 portfolios. Table 4 shows the estimation results.

Tab. 4: Result of Linear Regression in Case of 13 Portfolio

Parameter	Value	SE	t-value	p-value
Constant	0.5363	0.357	1.502	0.1612
Intercept	0.2049	0.6018	0.3405	0.7399
R-Squared	0.0104			
Adj R-Squared	0.0795			
Obs	13			

Table 4 shows that the linear CAPM presents a poor explanation of the rate of return volatility in terms of changes in the systematic risk of portfolios,

which could be attributed to the incompatibility of data from the Tehran Stock Exchange with the linear CAPM model or the small number of observations (13 portfolios), thereby reducing the accuracy of estimations. Figure 5 shows the 2D regression line and scatter plot of 13 portfolios.

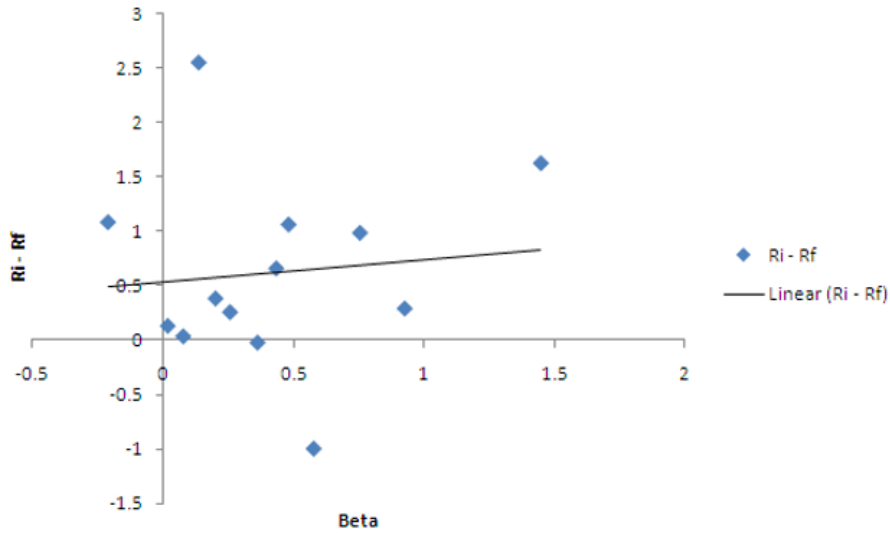


Fig. 5: Regression Line and Scatter Plot of Portfolio Performances

The linear and simple CAPM regression model is now estimated for the 120 portfolios. Table 5 shows the estimation results.

Tab. 5: Result of Linear Regression in Case of 120 Portfolio

Parameter	Value	SE	t-value	p-value
Constant	0.4344	0.1076	4.0333	0.0001
Intercept	0.3411	0.1769	1.9277	0.0000
R-Squared	0.0305			
Adj R-Squared	0.0233			
Obs	120			

The comparison of Tables 4 and 5 suggests that the larger number of portfolios has increased the significance of the coefficients, proving the explanatory ability of linear CAPM on data.

### 4.3 Validity of CAMP Model

This section will answer the third research question. For the 13 portfolios, linear CAPM became insignificant for the data. Therefore, validating the consistency

of the model's coefficients with CAPM's prediction will resolve any doubts. However, estimating the model with 120 portfolios increased the significance of coefficients due to the larger number of observations. Although the regression slope was insignificant with the first error level of 5%, it was significant with the 10% and even 6% error levels. Therefore, it is possible to comment on the compatibility of the beta coefficient and intercept with CAPM values.

Tab. 6: Validity of CAPM's Claim

Parameter	Estimated Value	SE	Actual Value	t-test	p-value
Constant	0.4341	0.1076	0.0000	4.0333	0.0001
Intercept	0.3411	0.1769	1.2538	5.1595	0.0000

Based on the Tehran Stock Exchange index and the one-year bank interest rate approved by the Central Bank, the average monthly market risk from April 2008 to March 2013 is 1.2538%. Table 6 suggests that the linear regression model on the data of 120 portfolios has a significantly different estimation than this real value and is incompatible with CAPM's claim. The same applies to the intercept. The linear regression's intercept, or the additional return after compensating for systematic risk, is significantly positive (opposite to zero). Note that the results are consistent with Black's claim Black et al. (1972) that the slope of the regression line is flatter than the theoretical slope predicted by CAPM. Nevertheless, contrary to Black's result, the simple linear model was not significant on a few of the observations (13 portfolios), and somewhat acceptable results were only obtained for a large number of observations (120 portfolios with 6%  $\alpha$  instead of 5%).

#### 4.4 Non-Linear Relationship Between Stock Price and Systematic Risk

In this section, I try to answer question 4: Is there a significant non-linear correlation between return on securities and systematic risk in the Tehran Stock Exchange? Note the dispersion of portfolio data in the two conditions of 13 portfolios and 120 portfolios in Figures 6 and 7. In both graphs, a quadratic curve has been passed through the data using the least squares method.

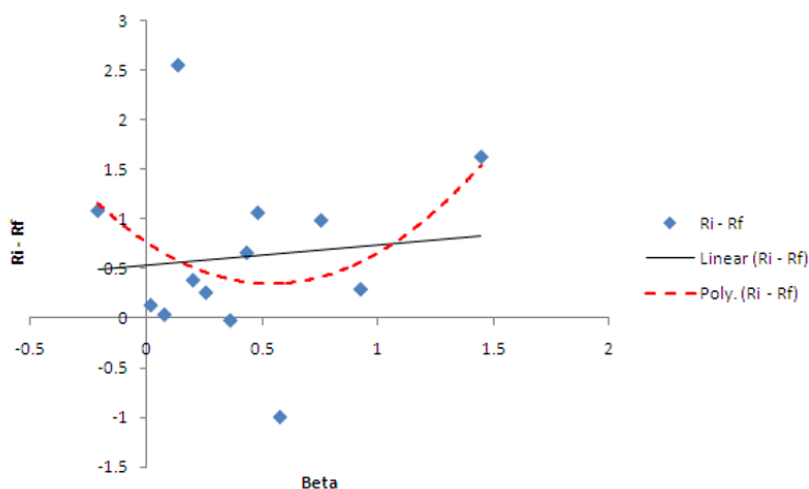


Fig. 6: Non-Linear Relationship for Case of 13 Portfolio

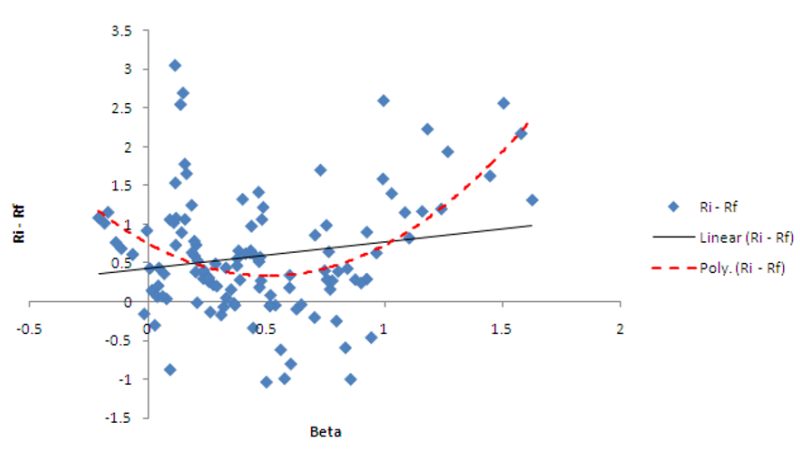


Fig. 7: Non-Linear Relationship for Case of 120 Portfolio

It seems that there is a non-linear correlation between the rate of return and systematic risk in the data of stock portfolios listed on the Tehran Stock Exchange, which has a logical explanation. The CAPM model had many simplifying assumptions, including the symmetric dividend ratio, and the distribution variance of stock dividends variable can be considered a good proxy for stock risk.

Another unrealistic assumption that guaranteed the linear correlation of CAPM was the possibility of investing and providing risk-free capital to the desired amount. At the same time, CAPM assumes that the portfolio repre-

senting the market is always fixed and specific, which is unrealistic in practice. This is especially the case in the Iranian economy, where the portfolio representing the market changed between 2008-2013 due to significant volatility in the exchange rate and the public's inclination towards investment in the gold, housing, and foreign exchange markets. All these events make the correlation between the rate of return and the systematic risk of stocks more complicated than a simple linear correlation. For deeper analysis, the following extended model is considered:

$$\overline{r_{pt} - r_{ft}} = \alpha_0 + \alpha_1\beta_p + \alpha_2\beta_p^2$$

As before, the variable on the left is the mean difference of the monthly return of portfolio  $p$  from the risk-free return. In this regard, the significance of the effect of systematic risk squared on the rate of return will be examined. Risk-free return is calculated according to the annual interest rate of banks approved by the Central Bank from 2008 to 2012 after conversion to monthly interest. The  $\beta_p$  variable is the beta of each portfolio. The 2nd-degree polynomial model above is estimated, and tables 7 and 8 show the results for the 13 or 120 portfolios.

Tab. 7: Non-Linear Relationship for Case of 13 Portfolio

Parameter	Estimated Value	SE	t-test	p-value
Constant	0.7684	0.3843	1.9999	0.0708
beta	-1.5636	1.4267	1.0959	0.2967
beta squared	1.4534	1.0711	1.3567	0.2020
Obs	13			
R-Squared	0.1643			

Tab. 8: Non-Linear Relationship for Case of 120 Portfolio

Parameter	Estimated Value	SE	t-test	p-value
Constant	0.7514	0.1160	6.4776	0.0000
beta	-1.6483	0.4331	3.8958	0.0001
beta squared	1.6262	0.3199	5.0834	0.0000
Obs	120			
R-Squared	0.2059			

As shown in tables 7 and 8, adding the square of systematic risk significantly improves the regression model's explanation ability of stock return volatility. It seems that the correlation between stock return and systematic risk in the Tehran Stock Exchange from April 2008 to March 2013 is a second-degree (quadratic) rather than a simple linear correlation.



## 5 Discussions

This study confirmed a non-linear correlation between stock return and systematic risk. It showed that in the single-factor CAPM that only measures the effectiveness of return in terms of systematic risk, a non-linear quadratic model has a greater explanatory ability than a simple linear model. Now, some questions can be raised:

- By adding other assets such as real estate, foreign exchange, and gold to the stocks, can a market-representative portfolio be formed such that considering the new market portfolio reduces the correlation between the rate of return and systematic risk of stock to the expected linear correlation of CAPM? In other words, to what extent is this non-linear correlation affected by the inefficient selection of the market portfolio?
- Does adding other explanatory variables such as company size, book value, and price-to-dividend ratio to the single-factor CAPM affect the significance of the square of systematic risk in terms of rate of return based on the beta?

## 6 Conclusion

This study raised four questions about the correlation between return rate and systematic risk to explain the CAPM in the Tehran Stock Exchange. The first question was related to a significant difference in the confidence interval of beta changes of companies between industries. It was shown that the beta confidence interval of the "Cement" industry is significantly ( $5\% \alpha$ ) different from the beta confidence interval of the "real estate," "chemicals," and "pharmaceutical" industries, and the confidence intervals of the remaining industry pairs all overlap and are not significantly different.

The second question was whether the assumption of a positive linear correlation between stock returns and systematic risk is confirmed on the data of the 13 portfolios (low number of observations) and 120 portfolios (high number of observations). With fewer observations, there was no significant linear correlation, whereas with a large number of observations, there was a positive linear correlation.

The issue in question three was whether the coefficients were consistent with CAPM prediction or significantly different in the case of significant linear correlation. With the high number of observations (120 portfolios), the beta coefficient is significantly lower than market risk (claimed by CAPM), and the intercept (in terms of additional return after compensation for systematic risk) is significantly positive and contrary to the CAPM claim.

In the end, it was shown that in addition to systematic risk (beta), the square of systematic risk is also vital in explaining volatility in the stock rate of return. After testing the hypothesis on a quadratic correlation between the rate of return and systematic risk, a nonlinear correlation was found in the Tehran Stock Exchange data.

## 7 Appendix

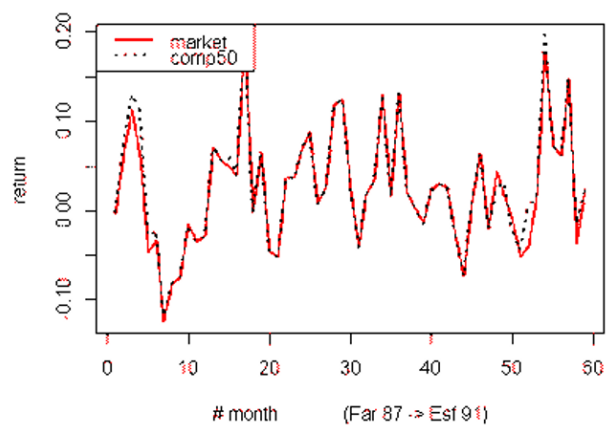


Fig. 8: Time series of TSE Index vs. rate of return of the weighted average of the portfolio consisting of the top 50 companies (It can be seen that the market is strongly influenced by the changes in the top 50 companies.)

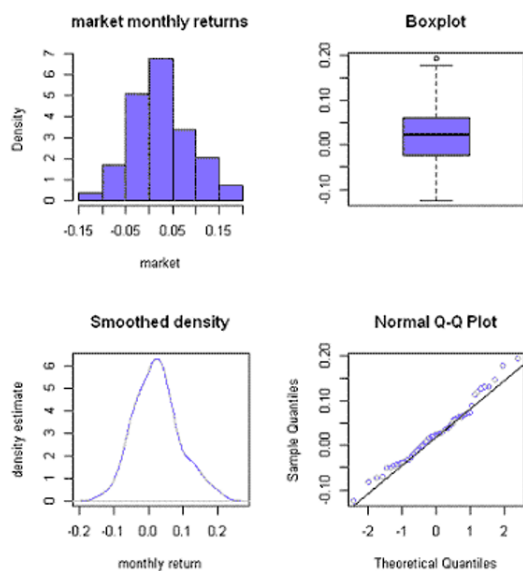


Fig. 9: Distributions of Market's Rate of Return

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