Journal of Asian Scientific Research
ISSN(e): 2223-1331
ISSN(p): 2226-5724
DOI: 10.55493/5003.v14i2.5072
Vol. 14, No. 2, 266-276.

URL: www.aessweb.com

Unveiling influential factors in the capital asset pricing model: A novel approach utilizing Taguchi method

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Article History
Received: 16 January 2024
Revised: 26 March 2024
Accepted: 12 April 2024
Published: 13 May 2024

Keywords
ANOVA
Beta
CAPM
DOE
Expected return
Risk rate
Taguchi method

ABSTRACT

This study uses a Design of Experiment (DOE) approach and the Taguchi method to examine how different factors affect the expected return within the framework of the CAPM. The Capital Asset Pricing Model (CAPM) is a financial framework that forecasts an investment's expected return by taking into account its systematic risk. This model factors elements like the risk-free rate, market risk premium, and beta to ascertain the expected return for a given asset. Typically, historical market data and financial analysis provide the inputs for CAPM. This method, frequently used in manufacturing and engineering, is modified for use in the financial domain to evaluate the importance of variables like beta, market risk premium, and the risk-free rate. The research identifies the factors that influence investment performance and shows how much each factor contributes to the expected returns. It is possible to ascertain each factor's percentage contribution to the expected return through statistical analysis. This work improves knowledge of CAPM and creates opportunities for improving investment decision-making processes by bridging the gap between financial theory and experimental design. Financial practitioners can achieve more reliable and accurate investment return forecasts by incorporating DOE techniques into their existing analytical toolkit.

Contribution/ Originality: This study introduces a novel approach to investigating the intricate connections between factors and expected returns within the CAPM framework by integrating the Design of Experiment (DOE) methodology, notably the Taguchi method, for the first time. The DOE approach, which adjusts to the financial environment and finds inspiration in manufacturing and engineering, reveals information about the relative importance of variables like beta, market risk premium, and the risk-free rate. The research measures each factor's contribution to the expected return and identifies the critical factors influencing investment performance by utilising statistical techniques.

1. INTRODUCTION

The CAPM, a widely used technique in finance, offers a framework for calculating the expected return of an investment based on its systematic risk. It gives an investor a method to determine the right return on investment or equity cost by integrating the asset's beta, market risk premium, and risk-free rate. Based on the rationale that investors are risk-averse and rational beings who want to maximize returns by balancing the relative importance of risk and reward, this theory was developed [1, 2]. The theory suggests a direct correlation between the expected return of an investment and its beta, thereby illustrating the relationship between systematic risk and expected return. Numerous factors influence the CAPM's calculations and results. The risk-free rate of return, beta, and market risk premium are the three main variables that substantially impact CAPM.

In the CAPM, the variables beta, interest rate (or risk-free rate), and expected return on the market all have important functions. Because they are interrelated and dependent on different market conditions and investor preferences, it can be difficult to determine which factor has the biggest impact. According to CAPM, each of these variables is essential for figuring out the expected returns of particular securities as well as the overall price of assets. Nevertheless, it is still unclear which parameter has the greatest influence. Changes in the risk-free rate influence variations in the cost of equity capital, while differences in the market risk premium can impact the expected returns for specific securities. Still, it's critical to recognise the assumptions and inherent limitations of CAPM. Variables not included in this list, such as company-specific risk, market dynamics, investor mood, and macroeconomic factors, can also influence asset prices and expected returns [3].

This study introduces a novel approach to investigating the intricate connections between factors and expected returns within the CAPM framework by integrating the Design of Experiment (DOE) methodology, notably the Taguchi method, for the first time. The DOE approach, which adjusts to the financial environment and finds inspiration in manufacturing and engineering, reveals information about the relative importance of variables like beta, market risk premium, and the risk-free rate. The research measures each factor's contribution to the expected return and identifies the critical factors influencing investment performance by utilising statistical techniques.

The application of the Taguchi technique is particularly useful when multiple factors influence the performance of a product or process. By carefully modifying different variables and analysing their effects on the response variable, the methodology helps determine the most crucial elements and their ideal configurations [4]. This raises quality, reduces variability, and boosts performance. While engineering and manufacturing widely use the Taguchi system, other domains such as finance or CAPM use it less frequently. Statistical methods unique to finance and investment analysis are frequently used to estimate and optimise parameters in financial models, such as the CAPM.

This study aims to accomplish three distinct goals. To start with, its goal is to identify the parameter in the CAPM framework that has the biggest impact on the expected return. Secondly, the study seeks to elucidate the process of employing a DOE approach in CAPM analysis, providing insights into the successful application of this experimental design method in the financial sector. Finally, by using quantitative methods, the study aims to ascertain the percentage contribution of each parameter, including beta, the risk-free rate, and the market risk premium, to the overall return on investments. These goals will help the research expand on knowledge of the variables influencing investment performance within the CAPM framework and improve financial analysis techniques. Utilising DOE methods inside the CAPM framework, this research aims to clarify the proportional contributions of each parameter to overall investment performance, as well as the relative effects of different parameters on expected returns. This comprehensive approach helps financial practitioners make more reliable and accurate investment return predictions by expanding their analytical toolkit and improving our understanding of CAPM. In short, the purpose of this research is to tackle the complicated issues present in CAPM analysis, provide an understanding of how various factors influence investment results, and establish the foundation for improved financial decision-making procedures. This research aims to open the door to a more thorough and complex understanding of investment dynamics by combining conventional financial theories with cutting-edge experimental design methodologies.

2. LITERATURE REVIEW

The robust optimization methodology known as the Taguchi method, named for the Japanese engineer Genichi Taguchi, finds application in a wide range of industries, including manufacturing, engineering, and product design [5]. By methodically locating and reducing sources of variation, this approach aims to enhance the performance and quality of processes or products. Taguchi's method uses DOE as a tool to simultaneously examine the effects of several parameters on a system. The main goal is to maximize system performance while reducing its sensitivity to changes in materials, input parameters, or environmental factors. By doing this, the Taguchi approach contributes to the creation of strong designs that are resilient to the uncertainties of the real world, resulting in improved quality and dependability. Hu, et al. [6] used an orthogonal array of L18, S/N ratio, and ANOVA to examine the effects of a rectifier with or without a ring, pressure inlet, distance between the rectifier and hot end, blade number, rectifier height, blade length, and blade inclination angle at three levels on the cooling efficiency of a vortex tube equipped. The researchers discovered that the blade length was the most important control factor, accounting for 36.9% of the cooling performance. (ii) The rectifier's height has minimal effect; it accounts for just 4.7% of the total cooling efficiency. (iii) the order of the other control parameters on the Coefficient of Performance was the following: the distance between the rectifier and the inlet (21%), whether the rectifiers had a ring or not (12.8%), were the other control parameters in order of importance on the coefficient of performance Hu, et al. [6].

Tian, et al. [7] examined the effect of rotational speed, feed speed, and tool diameter at 3 levels using Taguchi L9 and S/N ratio. It was found that rotational speed is the most significant factor that impacts bone drilling force and temperature Tian, et al. [7]. Ogbonna, et al. [8] used the Taguchi L9 and S/N ratio methods to find which parameter current, voltage, and gas flow rate had a greater impact on tensile strength (TS), yield strength (YS), the percentage elongation (PE), and hardness (H). It was found that voltage impacts more on TS, YS, and PE and current has more significance on H Ogbonna, et al. [8].

Dar, et al. [9] used the Taguchi method, analysis of mean, and ANOVA to find which factor impacts more on the company's goodwill. It was found that the number of purchase periods and average profit have more significance for a company's goodwill by using the super profit method to calculate the goodwill value [9].

Despite the Taguchi method's widespread application in various fields, its application in the CAPM context is less common. To improve comprehension and systematically optimise investment strategies, this research gap highlights the importance of investigating the possible inclusion of DOE techniques, such as the Taguchi method, into CAPM analysis. Financial analysts may be able to determine and rank the most important factors influencing projected returns by utilizing the methodical approach of the Taguchi method. This will improve portfolio performance and the process of making investment decisions.

3. METHODOLOGY

Taguchi's approach places a strong emphasis on the utilization of designed experiments to investigate the effects of several elements at once. By changing the levels of each factor in a planned way based on the orthogonal arrays, the Taguchi method makes it possible to accurately measure the effects and interactions of factors. The Taguchi methodology, developed by Genichi Taguchi, is a statistical DOE method used to improve the performance of a product or process. By reducing the volatility in the response variable, it seeks to pinpoint the most important variables and their ideal levels. Numerous industries, including manufacturing, engineering, and quality improvement, use the Taguchi system extensively Dar, et al. [9].

Barrado, et al. [10] provided a systematic process breakdown of the stages in the Taguchi methodology. First, the response variables, or experimental values, are defined. Next we determine the potential input factors and their corresponding levels. After that, an appropriate orthogonal array (OA) is chosen to make the experimentation process easier. Next, we assigned the identified factors to the columns of the selected OA. Once the experimental setup is complete, we carry out the experiments and record the output values obtained. These recorded values are then subjected to statistical analysis to identify any patterns or noteworthy effects. The analysis goal is to determine which factor levels have a significant impact on the response variable. To eliminate any doubt regarding the conclusions reached through the experimentation process, a confirmation test is carried out to verify the optimality of the determined combination. Informed decision-making and optimisation are ultimately the result of this methodical approach, which guarantees a thorough and intense examination of the factors influencing the response variable [10].

Figure 1 provide the Taguchi DOE processes.

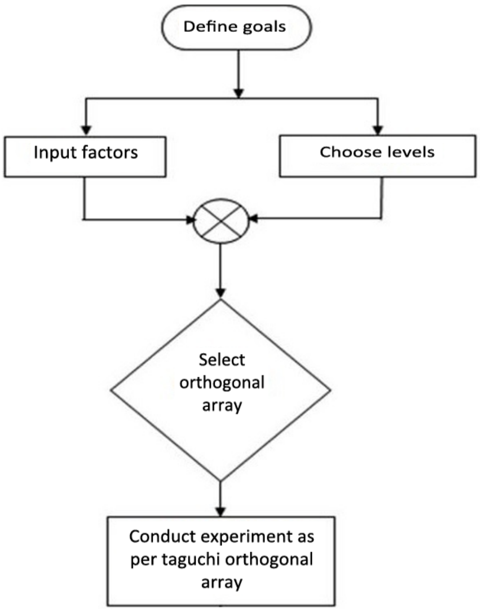

Figure 1. Flowchart of Taguchi design.

3.1. Taguchi Design

The effects of different factors on the expected return are systematically looked into in this study using the Taguchi OA design and an L16(4^3) array within the framework of the CAPM. The L16 array has three factors with four levels each, allowing for 16 experimental runs. This makes it an effective way to investigate factor interactions and optimise results. One of the most important steps in the experimental design process is choosing the factors and the relative amounts of each. This study focuses on the three key factors: beta, market risk premium, and risk-free rate. These crucial components of the CAPM have demonstrated a significant influence on investment outcomes. It is possible to evaluate each factor's effects on the expected return in detail by changing it at four different levels. Using a Full Factorial Design (FFD) with three factors at four levels each would require 64 runs, which is a significant amount of experiments. However, with only 16 experiments, we got significant results by utilising the Taguchi OA. This effectiveness in experimental design allows for more efficient and economical investigation of relationships between factors and results [11].

4. CAPM

The CAPM is a well-known financial model for calculating expected returns on investment based on systematic risk. William Sharpe, John Lintner, and Jan Mossin were among those who originally presented it in the 1960s [12]. The CAPM's primary goal is to build a relationship between an asset's expected return and its beta, which gauges the asset's sensitivity to market fluctuations. The model assumes that investors are risk-averse, logical people who want to maximise profits while considering the trade-off between reward and risk.

The key components of the CAPM are:

Risk-Free Rate: The return an investor can be certain of earning by investing in low-risk securities, mainly government bonds, is known as the risk-free rate. It serves as the risk-free baseline return.

Market Risk Premium: The market risk premium is the additional return that investors anticipate receiving in exchange for assuming the systematic risk connected with the market as a whole. It reflects the compensation investors must receive for taking on risk above and beyond the risk-free rate. Beta: In comparison to the entire market, beta measures the systematic risk of a single asset or portfolio. It measures how sensitive the asset is to changes in the market. A beta value larger than 1 denotes greater market volatility, whilst a beta value less than 1 denotes reduced market volatility [13].

The CAPM formula is as follows:

Expected Return = Risk-Free Rate + Beta × (Expected return on market - Risk-Free Rate)

$$E(R_I) = R_f + \beta[E(R_m) - R_f]$$

Or

Expected Return = Risk-Free Rate + Beta × (Market Risk premium)

5. ANALYSIS AND RESULT

The observed values of the various factors at various levels are shown in Table 1.

Table 1. Observed values of various.

Factors			
Levels	**Rate (r)**	**Beta**	**Exp. market return**
1	0.025	0.1	0.1
2	0.5	0.2	0.15
3	0.8	0.3	0.2
4	0.2	0.4	0.25

Table 1 provides the observed values of the various factors, including the rate (r), beta, and expected market return, each at four different levels. These values serve as the basis for the experimental design and allow for a comprehensive examination of the relationships between the factors and the expected return on investment.

The experimental design is Taguchi L16 OA for expected investment values (CAPM). There are 16 experiments, each with a distinct level. We ran the experiment using the Taguchi L16 OA method to investigate the impacts of three components (beta, rate, and expected rate on the market) at three levels each. Table 2 presents the outcomes (expected return on investment) from four application using Taguchi L16 approach.

Table 2. TAGUCHI L16 DOE with the expected rate on investment using CAPM.

Exp. no.	Rate	Beta	Exp. market return	Expected return
1	0.025	0.1	0.1	0.0325
2	0.025	0.2	0.15	0.05
3	0.025	0.3	0.2	0.0775
4	0.025	0.4	0.25	0.115
5	0.05	0.1	0.15	0.06
6	0.05	0.2	0.1	0.06
7	0.05	0.3	0.25	0.11
8	0.05	0.4	0.2	0.11
9	0.08	0.1	0.2	0.092
10	0.08	0.2	0.25	0.114
11	0.08	0.3	0.1	0.086

Exp. no.	Rate	Beta	Exp. market return	Expected return
12	0.08	0.4	0.15	0.108
13	0.1	0.1	0.25	0.115
14	0.1	0.2	0.2	0.12
15	0.1	0.3	0.15	0.115
16	0.1	0.4	0.1	0.1

Responses are measured when tests are conducted according to specifications. As a result, computations are performed, and the outcomes are organized in tabular form. The outcome of the process performance outputs for the expected return on investment is shown in Table 2 [11].

Table 3. Response table for means.

Level	Rate	Beta	Exp. market return
1	0.069	0.075	0.067
2	0.085	0.086	0.083
3	0.100	0.097	0.099
4	0.112	0.108	0.113
Delta	0.044	0.033	0.044
Rank	2	3	1

5.1. Analysis of Response Mean and Main Effects

The average value at various levels for an expected return on investment is shown in Table 3, and the delta value indicates that the expected market return is the most significant (rank 1) and beta has the least effect (rank 3) [14].

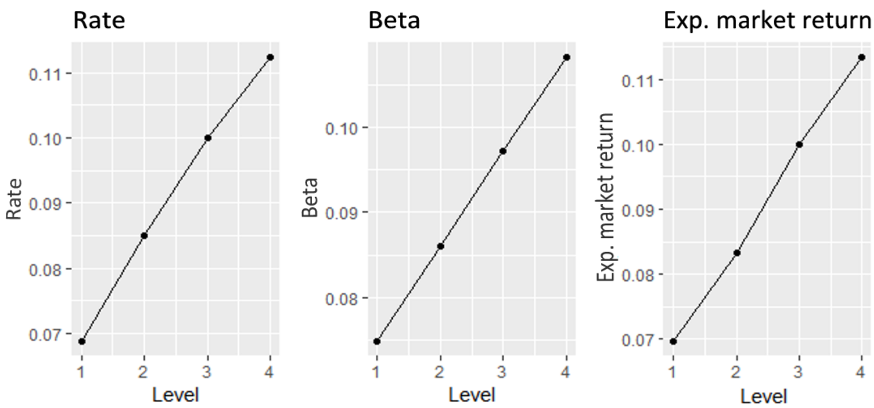

Figure 2. Main effects for mean.

Several factors affect the expected returns on investments within the framework of the CAPM. Beta is first and foremost an indicator of how sensitive a security's returns are to shifts in overall market returns. Indicating higher expected returns, higher beta values imply increased systemic risk attached to a particular security or portfolio. Furthermore, taking into account the time value of money, the risk-free rate—typically symbolised by the yields on government bonds—creates a foundation for projected earnings. We compared a lower rate, the market portfolio and all other investments have higher expected returns, which has an impact on overall asset pricing. The expected returns for all investments, including the market portfolio, typically rise when the risk-free rate rises. The positive slope of the rate, as shown in Figure 2, indicates a higher return. Finally, investors' expected returns from investing across the board in the market portfolio are reflected in the expected return on the market. This expectation takes into consideration the market risk premium, which is the additional return that investors demand in exchange for taking on systematic risk. Figure 2 illustrates how market conditions and projected returns on investments interact, with a higher expected return on the market generally translating into higher expected returns for particular assets within the CAPM framework. Therefore, the expected return on the market significantly influences the projected returns of certain securities within the CAPM [15].

5.2. Regression Analysis

Regression coefficients express the degree and direction of the relationship between a predictor and response variable.

Table 4. Regression coefficient: Beta, rate and expected market return.

Predictor	Coef.	SE coef.	T	p
Constant	-0.025	0.005	-4.58	0.001
Rate	0.572	0.041	13.87	0.000
Beta	0.111	0.010	10.55	0.000
Exp. market return	0.296	0.021	14.06	0.000

CAPM estimates the return on asset or investment using rate, beta, and the expected market return. The magnitudes of the coefficients for each factor are comparable. Compared to the standard errors of the coefficients for rate and beta, the expected market return coefficient has a lower standard error. Since the obtained p-value is less than typical significance thresholds of 5%, we can determine that the factor's coefficient is identical to zero. As demonstrated in Table 4, a positive coefficient means that as a component increases, the response variable will also rise.

5.3. Normality

In Figure 3, plots the average response for the projected return on investment as the primary effect. Figure 3 displays a normal probability plot vs. residual, where the residuals are seen to be near the straight line, suggesting a normal distribution [16].

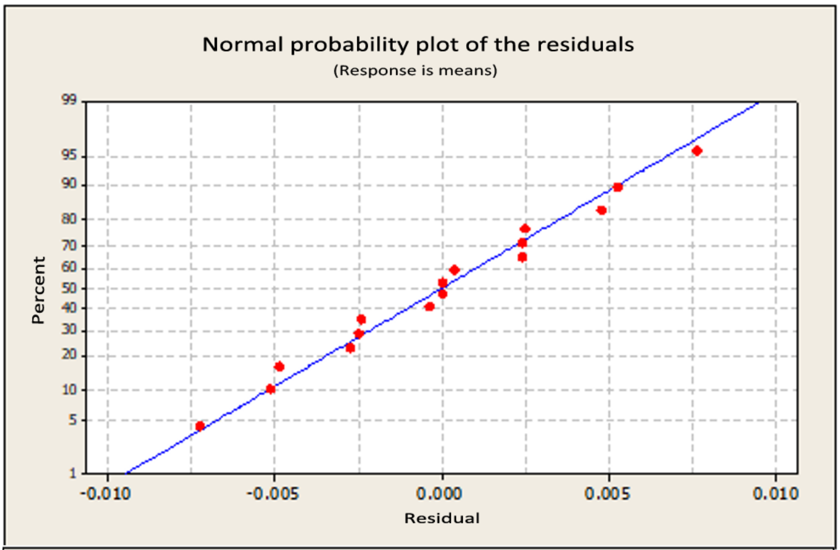

Figure 3. Normal plot.

5.4. Determine the Optimum Combination

Determining the ideal response value setting is one of the goals of the current investigation. For maximization of expected return on investment value, the optimal setting is chosen based on the higher value of factors at their levels presented in Table 3 for expected value on investment value. According to Table 3, the following are the most optimal input factor combinations:

$$R_{f4},\ \beta_4, E(R_m)_4$$

Where: R_{f4} is the value of the rate at the fourth level, β_4 is the value of beta at level 4 and similarly $E(R_m)_4$ is the value of the expected market rate at level four. All the values at level four are maximum and it indicates that the maximum value of all the above factors will provide you with the maximum return.

5.5. Analysis of Variance (ANOVA)

To test the null hypothesis, compare the term's p-value to your significance threshold to see if there is a statistically significant relationship between the response and each term in the model. The idea that there is no connection between the word and the answer is known as the null hypothesis. Generally, a significance threshold of 0.05 is considered appropriate, represented by α or alpha. A significance level of 0.05 indicates a 5% chance of assuming a link when none exists. There is a statistically significant correlation between the response variable and the term, according to Table 5, where the p-value is smaller than the significance level.

Table 5. Analysis of variance for means.

Factors	Degree of freedom	Seq SS	Adj sum square	Adj. mean square	P	Percentage contribution	Rank
Rate	2	0.004	0.004	0.001	0.00	37.589	2
Beta	3	0.002	0.002	0.00	0.002	21.676	3
Exp. market return	3	0.004	0.004	0.001	0.00	38.562	1
Residual error	6	0.000	0.000	0.000		2.173	
Total	15	0.010					

The percentage contribution can be estimated by the formula (Adj. SS/Total Adj. SS) *100 [17].

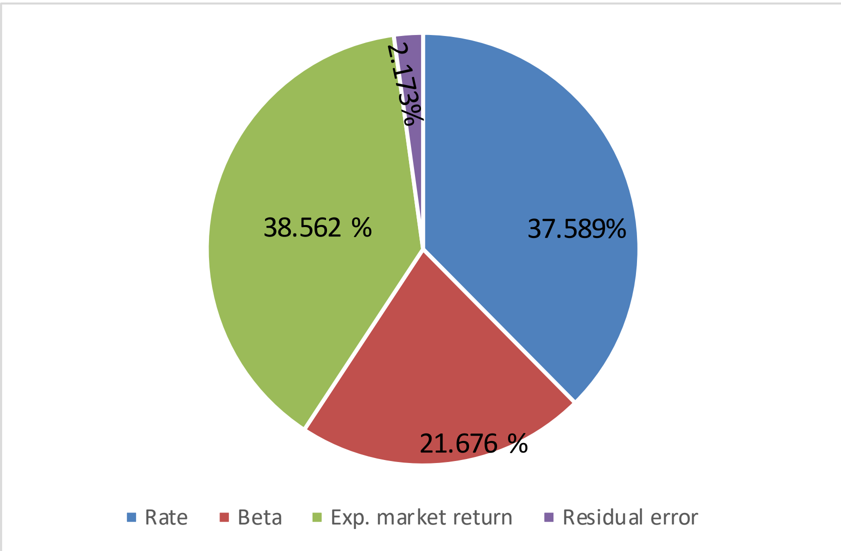

Figure 4. Percentage contribution.

According to Figure 4, the factor that has the most significant impact on the CAPM is the expected market return, which accounts for 38.56% of the variation. The rate factor, which contributes 37.58% to the CAPM, follows closely. The beta factor has the least impact, contributing only 21.67% to the CAPM.

6. ADDITIONAL FACTORS INFLUENCING CAPM PREDICTIONS

1. Investor Risk Aversion: According to CAPM, investors want higher expected earnings to accept more risk since they are risk-averse. Changes in investor risk aversion or mood may have an impact on the expected returns predicted by the CAPM, as well as the needed return requested by investors.

2. Market Conditions: Market variable such as economic concerns, industry changes, and investor sentiment can all have an impact on expected returns and asset value, beyond what the CAPM predicts. These variables bring new potential sources of risk and reward that the model might not be able to fully account for.

3. Macroeconomic Factors: Asset prices and expected returns may be affected by changes in macroeconomic variables, including inflation, gross domestic product growth, interest rate policy, and currency exchange rates. CAPM, which assumes a single-factor beta exposure to the merchandise, may not fully capture the impact of these macroeconomic factors on asset pricing.

4. Market Efficiency: The CAPM assumes that markets are effective and that asset prices promptly reflect all relevant data. The CAPM forecast could, however, differ if markets are not entirely efficient due to information asymmetry, market frictions, or investor behavioural biases.

7. DISCUSSION

This study briefly discusses and uses the Taguchi methodology in the experimental design. The systematic examination of several factors and their levels at the same time is made possible by Genichi Taguchi's robust optimisation approach, the Taguchi method. Researchers can effectively assess how different parameters affect system performance by going through a structured set of steps, such as defining response values, determining input factors and their levels, choosing orthogonal arrays, running experiments, and interpreting the findings. Using the CAPM as a framework, this study looked into the expected return on investment using the Taguchi L16 orthogonal array design. The experimental designs, which consisted of 16 separate experiments, varied three parameters at four different levels: beta, risk-free rate, and expected market return. These experiments' results shed important light on the connection between expected returns and input parameters. The experimental design was based on the observed factor values at various levels. Because of these observed values, a thorough analysis of the relationships between the CAPM framework's predictability and the factors of rate, beta, and expected market return was possible. The analysis of the data showed some interesting conclusions about how each component affected the expected return. The response table for means demonstrated the distinct ways in which rate, beta, and expected market return influence the expected return on investment. Interestingly, the delta values showed that the expected market return was the most important factor, with the rate and beta coming in second and third, respectively. The correlations between the predictors (rate, beta, and expected market return) and the response variable (expected return on investment) were further clarified through regression analysis. The magnitudes and significance of these relationships were illustrated by the regression coefficients shown in Table 4. All the three factors significantly influenced the expected return on investment, with the expected market return displaying the strongest correlation, as indicated by the coefficients. The study also discussed other factors that might affect CAPM predictions, beyond the variables it took into account. The results of this study offer important insights into the factors influencing expected returns within the CAPM framework, adding to the body of knowledge already available on asset pricing models. Investor fear of risk, market conditions, economic variables, and market efficiency were identified as critical elements that could influence expected returns and asset valuations. By combining the Taguchi methodology with CAPM analysis, researchers can improve decision-making processes in financial markets by better understanding the intricate relationships between investment outcomes and input parameters.

7.1. Limitation and Future Scope

There are a few limitations to note, despite the study using the Taguchi methodology to provide insightful information about the factors influencing expected returns within the CAPM framework. First off, by focusing only on these three variables—beta, risk-free rate, and expected market return—the study may miss other important aspects of asset pricing. Furthermore, even though the Taguchi approach works well for experimental design, it might not adequately represent the intricacy of financial markets and the interactions between different economic variables. Furthermore, bias or inaccuracies could be introduced by the study's reliance on historical data for parameter estimation, especially in environments with dynamic markets. Furthermore, the unreliability of its underlying assumptions, such as market efficiency and rational investor behavior, may impact the predictive ability of the CAPM model. By including a wider range of variables, applying more advanced modelling techniques, and investigating alternative asset pricing frameworks, future research could address these limitations.

This work provides a number of directions for further investigation and real-world application. To get a better idea of how these factors affect expected returns within the CAPM framework, future research could look into adding more variables to the experimental design. These variables could investor sentiment, geopolitical factors, or technological advances. Furthermore, performing long-term studies to evaluate the robustness and stability of the relationships found in this study over time may provide important new understandings of how dynamic asset pricing is. From a practical perspective, financial professionals and policymakers can utilize the results of this study to formulate more successful risk management and investment strategies. Through the application of experimental design methodologies such as Taguchi, policymakers can improve the precision and dependability of financial models, thereby increasing investor confidence and market efficiency. Policymakers should also think about enacting rules or guidelines that support the use of sophisticated experimental design methods in financial practice and research, encouraging creativity, and raising the standard of investment decision-making in the financial sector. Ultimately, this paper's future focus is on deepening our knowledge of asset pricing dynamics and producing insights that practitioners and policymakers can use to inform their decisions.

8. CONCLUSION

In conclusion, in estimating expected returns on investments, the CAPM emphasises the importance of beta, the risk-free rate, and the market return. However, because these variables have interdependent effects that are influenced by different market dynamics and investor sentiments, it is difficult to identify one that is singularly dominant among them. Though it offers a fundamental framework for estimating expected returns, the CAPM has certain assumptions and limitations. In addition to the factors explicitly considered in the CAPM, market efficiency, liquidity, and firm-specific risks play a significant role in real asset pricing. As a result, to improve predictive accuracy and properly advise investors, practitioners frequently supplement CAPM with other variables and models. The applicability of CAPM should be critically evaluated, and researchers and investors alike are urged to investigate alternative strategies that take behavioural nuance and real-world complexity into account. Enhancing market efficiency and improving asset pricing models require policy measures such as encouraging transparency, minimising information asymmetry, and boosting investor education. By recognising the advantages and disadvantages of CAPM, investors can better navigate investment environments and make informed, confident adjustments to changing market conditions by recognizing CAPM's advantages and disadvantages.

Funding: This study received no specific financial support.
Institutional Review Board Statement: Not Applicable.
Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: Writing, A.A.D. and M.M.; design, A.A.D. and A.R.F.; literature review, results, N.A. revision, M.S.K. and A.R.F. All authors have read and agreed to the published version of the manuscript.

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