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A Review of the Theory and Development of the Capital Asset Pricing Model

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Abstract. Since William Sharpe introduced the Capital Asset Pricing Model (CAPM) in the 1960s, it has profoundly influenced asset pricing, portfolio management, and corporate financial decision-making. This work employs a comprehensive literature review methodology, utilizing comparative and inductive analysis to elucidate the primary research trajectories and developmental patterns of the CAPM. The Capital Asset Pricing Model (CAPM) was formulated on the foundation of Markowitz's portfolio theory and introduced by William Sharpe. It has since had extensions, including the APT model, the three-factor model, and the four-factor model, along with the latest use of machine learning techniques, aligning capital price more closely with actual market conditions. The research conclusion indicates that, firstly, although the CAPM has certain limitations, its theoretical simplicity and logical rigor make it an important asset pricing tool for investors. Secondly, multi-factor models have become a new path for the development of the CAPM, and further increasing factors can enhance the model's explanatory power. Finally, behavioral finance provides a new perspective for understanding the limitations of the CAPM.

Keywords: Capital Asset Pricing Model, Behavioral Finance, Asset Pricing, Multi-factor Model, Market Portfolio

1. Introduction

The introduction of the capital asset pricing model (CAPM) has sparked ongoing debate in academic circles on its applicability. Sharpe proposed the conventional Capital Asset Pricing Model (CAPM) and asserted that asset returns are only influenced by market risk β [1]. In addition, Fama & MacBeth tested CAPM through cross-sectional regression and found that β has a strong explanatory power for stock returns [2]. However, with the increasing complexity of financial markets, the CAPM return forecasting framework based on a single market risk factor gradually exposes its limitations and its explanatory power faces empirical challenges. Subsequently, many scholars modified the capital asset pricing model, which has been greatly expanded up to now. For instance, Jensen and Black reduced the assumption of risk-free lending and introduced zero β [3]; Merton expanded the single-period model into a multi-period framework and incorporated state variable risk. The rise of multi-factor models, including three-factor and four-factor models [4]. Despite the emergence of revised models of the capital asset pricing model, current research predominantly concentrates on a singular theoretical aspect (such as factor expansion), failing to provide a

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systematic analysis of the comprehensive logical progression of the capital asset pricing model's theoretical evolution. Therefore, this paper will systematically deconstruct the evolution path of CAPM from single-factor benchmark model to behavioral finance expansion through literature analysis of existing scholars' research. The capital asset pricing model has a profound impact on investment practice, and understanding the applicability and limitations of the capital asset pricing model can help investors make scientific investment decisions.

2. Development and deduction of capital asset pricing model

2.1. Standard capital asset pricing model

According to Sharpe's research, the equation of the standard capital asset pricing model is as follows [1]:

$$E(R_i) = R_f + \beta(E(R_m) - R_f \tag{1}$$

Where, $E(R_i)$ is the expected return rate of assets; R_f is the risk-free interest rate; R_m Is the expected return rate of the market portfolio, which refers to the portfolio composed of all risky assets in the market; β is the coefficient measuring systematic risk.

2.1.1. Core assumptions

This model is a theoretical analysis model conducted under the following core assumptions, which include:

1) Investor behavior hypothesis. This assumption holds that investors in all markets are rational people, that is, they possess absolute rationality and the ability to objectively analyze the complex information in economic operation, and all investors pursue maximum benefits, that is, to pursue the highest return under a given risk or undertake the lowest risk under a given return. Meanwhile, these investors only focus on the expected returns and risks of assets to make investment decisions.

2) The perfect market hypothesis. In this assumption, there are no transaction costs, taxes or information barriers in the market. Furthermore, all market assets are divisible and tradable, allowing all investors to borrow and lend funds at an identical risk-free interest rate.

3) Asset and market portfolio assumption. All investors may possess identical portfolios of risky assets while concurrently holding varying proportions of those assets.

2.1.2. Limitations

The capital asset pricing model is overly idealistic. The market in reality is one with problems such as transaction costs, taxes and information asymmetry. Moreover, investors are not entirely rational. Each investor has a different risk preference. Secondly, the capital asset pricing model identifies risk factors only by relying on the β coefficient (market risk), thereby ignoring other risk factors. Furthermore, in the real market, due to the lack of certain security-related data, it is difficult to find an accurate β.

In addition, the capital asset pricing model does not take into account the factors of behavioral finance. Because in the theory of behavioral finance, it is pointed out that investors lack rationality. Due to the influence of information asymmetry and cognitive bias, this leads to the inability of investors to correctly assess the expected returns and risks of assets. Shefrin, H. Statman proposed the Behavioral Asset Pricing Model (BAPM) rooted in behavioral finance theory [5]. Behavioral

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finance theory also points out that the market is not always completely efficient, and the perfect market assumption in the capital asset pricing model conflicts with it.

2.2. Expansion of capital asset pricing model

Although the capital asset pricing model (CAPM) lays the basic theory of asset pricing, there is a big gap between its core assumptions and the real market. Therefore, a large number of scholars began to expand the capital asset pricing model, including the intertemporal capital asset pricing model (ICAPM), the consumer capital asset pricing model, the Fama-French three-factor model, the Carhart four-factor model, and the Fama-French five-factor model.

2.2.1. Dynamic model

1) Intertemporal capital asset pricing model

Because the traditional capital asset pricing model is based on single-period static investment, while in reality, investors need to consider economic changes, such as interest rates, exchange rates and inflation rates, etc. So Merton proposed the intertemporal capital asset pricing model, and its expression is as follows [4]:

$$E\left(R_i\right) = R_f + \beta_{i,m}\left(E\left(R_m\right) - R_f\right) + \sum_{K=1}^{K} \beta_{i,k}\lambda_k \tag{2}$$

Where $\beta_{i,m}$ is market exposure risk; $\beta_{i,k}$ refers to the risk exposure of asset i to k state variables (e.g., inflation rate and GDP growth rate); λ_k is the risk premium for k state variables.

This model shares the same theoretical basis as CAPM. Both believe that the market is in an equilibrium state, and at the same time, the prices of assets are affected by market risks. Therefore, the intertemporal capital asset pricing model still retains the market risk factor β . Furthermore, this model incorporates macro economic factors for the first time. Compared with the traditional capital asset pricing model, it is closer to reality and the model is also more explanatory. However, there are also limitations. Because state variables are difficult to measure accurately, they may have poor operability in empirical research.

2) Consumer Capital Asset Pricing Model

Breeden correlated asset returns with variations in consumption and introduced a consumer-based capital asset pricing model [6]. The expression of the consumer capital asset pricing model is as follows:

$$E\left(R_{i,t+1}\right) - R_j \approx \gamma \cdot Cov\left(R_{i,t+1}, \frac{\Delta C_{i+1}}{C_t}\right) \tag{3}$$

Among them, R_f represents the risk-free rate of return; $R_{i,t+1}$ is the yield rate of the asset in maturity; $\frac{\Delta C_{t+1}}{C_i}$ represents the growth rate of consumption; $Cov\left(R_{i,t+1}, \frac{\Delta C_{t+1}}{C_i}\right)$ is the covariance of asset returns and consumption growth, namely "Consumption β ". This indicator reflects the ability to hedge against consumption risks. The larger this indicator is, the higher the expected return will be. F represents the risk aversion coefficient. The larger this coefficient is, the greater the investor's sensitivity to fluctuations in consumption will be, and thus the higher the requirement for risk premium will be.

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This model extends the standard capital asset pricing model by integrating asset price with consumers' intertemporal consumption choices, thereby theoretically delineating the connection between asset returns and consumption growth. For example, Mehra and Prescott found that the equity risk premium predicted by theory in the US market is much lower than the value actually observed, which is the "equity premium puzzle" [7]. In the European market, the "equity premium puzzle" also exists. Marco, D & Gabriele, C used the European financial market data from 2000 to 2021, modified the traditional consumer capital asset pricing model, and introduced the factor of "consumption inertia." The equity premium puzzle still exists in European financial markets, but they found that their modified model could not explain the premium puzzle before the 2008 financial crisis [8]. However, after the financial crisis, the traditional model can explain the low premium problem, and the equity premium in the European market begins to decline, which means that the equity premium puzzle is "partially resolved" in the European market.

However, according to the research of Han and Chu on the Chinese stock market, it is found that there is no "equity premium puzzle" phenomenon in China [9,10].

2.2.2. Multi-factor model

To enhance the explanatory capacity of the capital asset pricing model for security prices, it has progressively evolved from a single-factor to a multi-factor framework. Based on the conventional capital asset pricing model, numerous scholars have proposed additional elements to develop a novel multi-factor model. Ross introduced the Arbitrage Pricing Theory (APT), founded on the no-arbitrage principle, which challenged the equilibrium pricing framework of the Capital Asset Pricing Model (CAPM).

1) Fama-French three-factor model

The three-factor model is a successful application of the APT model, which was proposed by Fama & French after finding that the capital asset pricing model could not explain the scale effect and the value effect. More risk dimensions are considered and the framework of risk and return is improved, which significantly improves the explanatory power of the model for cross-sectional stock returns [11]. Moreover, empirical evidence indicates the presence of systematic excess returns in small-market capitalization equities and those with a high book-to-market ratio. In addition, Shi Haotian's research found that the three-factor model has a strong explanation for the excess returns of the main board market of the Shanghai Stock Exchange [12,13]. This may be because small-cap companies lack assets to resist risks, and their returns fluctuate greatly when they encounter market risks. High market capitalization companies are more stable because they have enough assets. These phenomena cannot be explained by a single market risk factor. However, this model also has limitations: it is difficult to explain the momentum effect anomaly and it cannot capture the structural changes of the factor premium.

2) Carhart's four-factor model

Carhart added the momentum factor (MOM) to the three-factor model, and the modified model captured the momentum effect discovered by Jegadeesh & Titman [14,15]. In terms of empirical research, Lewellen's study shows that the four-factor model incorporating the momentum factor can well capture excess returns, compensating for the limitation of ignoring the momentum effect in the three-factor model. However, highly volatile growth stocks are an important component of the momentum portfolio. Therefore, the four-factor model can effectively improve the interpretation of highly volatile growth stocks [16].

3) Fama-French five-factor model

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The five-factor model is that Fama & French add profit factor (RMW) and investment factor (CMA) on the basis of the three-factor model [17].

Fama & French took all listed companies including Nasdaq, the New York Stock Exchange and the American Stock Exchange as samples to conduct empirical research to test the effectiveness of the five-factor model. It has higher explanatory power in terms of average excess return, expected return and goodness of fit of the model [17]. Ammann, M and other scholars pointed out that the five-factor model can effectively explain anomalies that cannot be captured by traditional models, such as momentum effect and abnormal investment efficiency [18]. In terms of empirical research, the effects of profit factor and investment factor are very significant and remain robust in different economic cycles, but the explanatory power of scale factor and value factor is weakened in the sample.

Mu Xuan's research indicates that in the Chinese market, the five-factor model is more significant than the three-factor model for scale and value elements; however the impacts of profit and investment factors are diminished [19].

3. Expansion of behavioral finance theory

The core idea of the traditional CAPM is that the expected return of assets is generally determined by systematic risk, while non-systematic risk can be offset by increasing asset holdings, so it does not affect the expected return. However, CAPM seems powerless in the face of some market "anomalies," so scholars began to question whether its theory is reliable.

Behavioral finance is different from standard financial theory in that the former holds that investors are not completely rational, and they will be affected by various factors in the investment process. At the same time, the sensitivity of investors to losses is much higher than that of returns to scale; that is, people care more about the degree of losses than the size of wealth.

Shefrin & Statman proposed the behavioral Asset Pricing Model (BAPM), which retained part of the contents of the traditional CAPM and introduced investor heterogeneity and cognitive bias on this basis to construct an asset pricing model that more closely fits the display market [5].

It is worth noting that BAPM does not simply reject the traditional CAPM, but relates the rational man assumption, and makes the model more explanatory in the face of market anomalies by classifying investors and introducing behavior β. The specific expression of BAPM is as follows:

$$E(R_i) = R_f + \beta_{ib}[E(R_b) - R_f] \tag{4}$$

β_{ib} represents the behavioral beta of asset i equivalent to behavioral portfolio b. This indicator measures the sensitivity of asset returns to the returns of the "behavioral portfolio". $E(R_b)$ is the expected benefit of the behavioral combination.

Unlike the traditional CAPM, BAPM also incorporates value expression factors. CAPM only considers the utilitarian needs of investors, such as costs and benefits. However, BAPM further considers value expression, that is, the investor's investment style, social status, etc. Statman believes that investors not only have material needs to pursue returns when conducting investment activities, but also have psychological needs to express their self-value and identity, while CAPM does not take into account the needs of investors to express their value.

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4. Discussion

From a single factor to five factors, the model has stronger explanatory power and can better explain the "anomalies" in the market. However, with the continuous increase of factors, the problem of factor redundancy appears in the model. In the future, the model also needs to be modified to improve the independence of factors. In addition, factors with "localization" characteristics can also be included according to different market development conditions, so as to promote the universality of CAPM and take into account its particularity. Of course, it is also feasible to deeply integrate traditional asset pricing and behavioral finance. Introducing a series of behavioral indicators, such as the investor sentiment index and market fear index, can effectively help investors understand market volatility and asset pricing, thus improving the practicability of the model.

As the information and technology era progresses, the accessibility of financial data has significantly enhanced, leading to corresponding advancements in asset pricing methodologies. Nevertheless, the conventional capital asset pricing model has struggled to accommodate the intricate and variable "market anomaly" by persistently extracting and integrating additional risk elements. Conversely, the financial market contains numerous high-dimensional datasets that may exhibit nonlinear characteristics, complicating the ability to accurately capture these traits within traditional pricing models that presume a linear relationship between asset returns and risk. Machine learning technology, due to its powerful algorithm support, can efficiently process these high-level data, and can quickly adjust according to new data to adapt to market changes. For example, when there are major macroeconomic fluctuations, machine learning models can quickly incorporate this information, so that the model can better explain "anomalies" in the market and produce more accurate results.

5. Conclusion

This article, through the review and sorting of the relevant literature on CAPM, draws the following conclusions:

1) Although the traditional CAPM has many limitations, this model is the first to take systemic risk as an important factor in asset pricing and establishes a theoretical framework of the linear relationship between risk and return.

2) From the perspective of empirical research, the explanatory power of CAPM is stronger in some relatively mature markets than in emerging markets. This is because in mature markets, the information transparency is higher, the market operation mechanism is more complete, and the transaction costs are lower. These conditions are closer to the hypothetical conditions in CAPM. However, emerging markets will greatly reduce the effectiveness of CAPM due to reasons such as information asymmetry and imperfect systems.

3) The transition from the single-factor model to the multi-factor model, alongside the enhancement of CAPM through behavioral finance theory. The model's explanatory power is consistently improving and increasingly aligns with real market developments. The optimal number of components to be picked for CAPM remains an unsettled subject.

The evolution of the capital asset pricing model is actually a process in which financial theories continue to develop and gradually adapt to the complexity of the real market. In the future, with the continuous development of financial theories and technological levels, capital asset pricing is expected to make greater breakthroughs in universality, explanatory power, predictability and operability.

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