Analysis of the Modern Financial Regression Model: CAPM and Fama-French

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Abstract: Contemporarily, financing pricing models are widely adopted in assets evaluations. This study will discuss the development and empirical testing of the CAPM, Fama-French Three-Factor Model (FF3), and the Five-Factor Model (FF5) in the context of modern asset pricing. The FF3 model improved upon the traditional CAPM by introducing size and value factors to better capture variations in stock returns. However, its inability to account for differences in profitability and investment behaviours led to the creation of the FF5 model, which adds profitability and investment factors. Empirical evidence suggests that while the FF5 model generally outperforms the FF3 model in explaining stock returns, particularly in the U.S. market, its performance is less consistent in other markets, such as China and Japan, indicating its limitations in diverse economic and regulatory environments. The review highlights the FF5 model's potential factor redundancy, inconsistent results across markets, and limited ability to capture certain stock behaviours as areas requiring further development. Future research directions include integrating artificial intelligence and behavioural factors to enhance the model's predictive power and applicability. This research concludes that while the FF5 model represents a significant advancement in asset pricing.

1 INTRODUCTION

In broad terms, finance revolves around the study of asset risk and return through mathematically lens. In the early 1960s, American economist William Sharpe and his colleagues revolutionized modern finance through the Capital Asset Pricing Model, providing foundation and framework for valuation of assets. The pioneering financial model applied widely in the 20th century for and William Sharpe was awarded the Nobel Price of Economic Science in 1990. In addition to the Markowitz Model assumptions on risk aversion of investor, the one-factor model added the assumptions of complete agreement of investors and risk-free rate borrow and lend (Fama & French, 2004). CAPM asserted a linear relationship between asset returns and market risk (Ross, 1978). Despite its theoretical simplicity and strong explanatory power, CAPM has faced criticism in practical applications, particularly when dealing with real-world markets characterized by incomplete information and heterogeneous investors (Fama, 1970; Epps, 1976).

To address the limitations of CAPM, Fama and French proposed FF3 model, introducing two additional factors to explain anomalies in stock returns that CAPM could not account for. The FF3 model demonstrated significant improvements in various empirical studies, particularly in explaining the excess returns of small-cap and value stocks (Fama & French, 1993).

Fama and French later introduced the FF5 which improves upon FF3, adding two additional factors to the original three. FF5 aims to reflect the drivers of stock returns, providing a more robust asset pricing tool for both academic and practical use (Fama & French, 2015). Empirical tests on developed global markets suggest an improvement to FF3 and that the regional models outperform global model (Cakici, 2015). This study will systematically review and analyse the existing methodologies on the CAPM, FF3, and FF5 models to explore their theoretical foundations, applications, and performance across different market environments.

This paper will first examine the history and theoretical expansion of the modern financial models and then assess their performance in empirical studies. Then the paper will compare the application outcomes of FF3 with FF5 across different markets. Through this literature review, I hope to highlight the limitations and prospects of these models in modern

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financial markets, incorporating the models with new emerging technologies of Artificial intelligence.

2 DEVELOPMENT FROM CAPM TO FAMA-FRENCH MODEL

2.1 History of CAPM

In modern finance, CAPM remains as a simplistic yet fundamental model for valuation of asset and estimation of portfolio performance. CAPM, introduced by Sharpe and Lintner, builds upon Markowitz's mean-variance optimization theory developed in the 1950s. Markowitz's model assume investors to minimize the variance and maximize the return rate of a portfolio. The model indicates prices of all assets reflect their market risk, represented by their beta coefficients. It distinguishes between systematic risk and unsystematic risk (risk specific to an individual asset), assuming that investors concerned with systematic risk primarily. It assumes every investor's portfolio follows the mean-variance optimization strategy and can borrow or lend unlimited amounts at the risk-free rate (Ross, 1978). Based on the assumptions, CAPM concludes on a linear relationship between the expected return and beta:

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

Beta represents the systematic risk of the market and depends on historical returns and market returns,

$$\beta_i = \frac{cov(R_i, R_M)}{\sigma^2(R_M)} \tag{2}$$

Beta also represents the slope of linear regression between the expected return and market return which provides information on sensitivity of individual stock given the fluctuating market return. Under the assumption of CAPM, the beta of riskless asset equals zero and the expected return of the portfolio must equal to the risk-free rate.

While CAPM provides a simplistic algebraic method to valuate asset, it has limitations due to assumptions on investors behaviors. It assumes an efficient market where all investors behave rationally, and they can borrow or lend at the risk-free rate. Contrary to this idealized assumption, market information is not fully transparent, transaction costs exist, and borrowing is not always possible at the risk-free rate, thereby weakening CAPM's effectiveness in real-world applications (Ross, 1978; Bartholdy & Peare, 2005). The assumption of investors caring only about mean-variance also reflects the flaw of CAPM. It is likely for investors to care for income in addition to the mean-variance analysis, thus undermining the portfolio's return variance as it misses such variables (Fama & French 2004).

2.2 CAPM TO FF3

Academia recognized the limitations to a single-factor model in valuating asset. Eugene Fama and Kenneth French introduced the FF3 in 1993, which added two additional factors—firm sizeand book-to-market ratio—to capture the effects of size and value on stock returns:

$$E(R_i) = R_f + \beta_1\big(E(R_m) - R_f\big) + \beta_2(SMB) + \beta_3(HML) \tag{3}$$

Intuitively, higher expected returns for small-cap stocks represented by the size factor will compensate investors for the additional risks associated with smaller firms, which may include higher volatility, less liquidity, and higher default risks. Small firms often have less access to capital, fewer resources to weather economic downturns, and are generally considered riskier investments compared to their larger counterparts. Investors demand a risk premium for holding that stocks, leading to higher expected returns relative to large-cap stocks (Fama & French 1992). FF3's logic builds on the premise that stock returns are influenced not only by their sensitivity to overall market risk but also by their exposure to these additional risk factors. By including these two additional factors, FF3 provides a more nuanced explanation of stock returns, reflecting the risk premiums investors demand for holding small-cap and value stocks due to their perceived higher risk.

2.3 Development of FF5

In 2014, Eugene Fama and Kenneth French extends the original model again with additional factors of profitability and investment. FF5 extends on logic of FF3 using factors of RMW and CMA,

$$E(R_i) = R_f + \beta_1\big(E(R_m) - R_f\big) + \beta_2(SMB) + \beta_3(HML) + \beta_4(RMW) + \beta_5(CMA) + \beta_0 \tag{4}$$

Here, RMW calculates the difference in returns between a portfolio of stocks with robust and weak portfolio. Profitability is typically measured by operating profitability. Research shows that firms with higher profitability tend to have higher stock returns, as they are often perceived as more stable and less risky investments. Profitable companies generate stronger cash flows and are better able to weather economic downturns, which justifies a risk premium on their returns (Fama & French, 2015). CMA calculates the difference in returns between firms that follow low asset growth and those that adopt high asset growth. The CMA factor captures the observation that firms with lower levels of asset growth tend to have higher future returns comparing to those with higher levels of asset growth. This can be attributed to the tendency of firms that invest aggressively to undertake riskier or less profitable projects, which may lead to lower future profitability and hence lower expected returns. Conversely, firms with conservative investment policies are generally viewed as more disciplined and less risky, resulting in relatively higher expected returns. If the Betas explain all cross-sectional variation of the portfolio, then β_0, or the intercept, equals zero (Fama & French, 2015).

FF5 bases in Dividend Discount Model (DDM) which suggests that expected returns are linked to profitability and investment patterns. DDM states that given the expected dividend $E(d_{t+\tau})$, the stock price:

$$m_t = \sum_{\tau=1}^{\infty} E(d_{t+\tau})/(1+r)^{\tau} \tag{5}$$

The relation given by DDM has implications on the expected return of an individual stock and CMA and RMW aim to explain cross-sectional variation under this model. Despite its broader scope, the FF5 model has faced several criticisms. One key criticism is the potential redundancy of the value factor (HML). Fama and French found that the HML factor's significance diminished with the inclusion of FF5 factors, raising questions about its necessity in the model (Cakici, 2015). Furthermore, the FF5 model's performance varies across different markets and portfolio constructions, suggesting that its applicability might be context dependent (Fama & French, 2015). The limitations suggest a need for empirical examination of the FF3 and FF5 Model performance.

3 APPLICATION AND DEVELOPMENT OF FAMA-FRENCH MODEL

3.1 Empirical Stuies

In the study on performance of FF3 and FF5 on portfolio of ten US sectors, researchers point out that FF5 explains the variability of sector portfolio better than FF3 (Sarwar et al., 2017). While both FF3 and FF5 outperform the benchmark of S&P 500, the result reveals a higher cumulative return and adjusted R^2 than that of CAPM and FF3. According to the research, FF5 alpha has higher adjust R^2 than that of FF3 alpha across all ten US sectors. The return of FF5 portfolio also have 7% higher return and 2% lower standard deviation compared to the buy-and-hold S&P 500. With trading on sector ETFs, long-only FF5 trading strategy has 5.53% of mean return while buy-and-hold S&P500 only has 2.05%. The researchers suggest that the factors of RMW and CMA betas of FF5 likely decrease alpha estimate in most sectors (Sarwar et al., 2017).

Research on the U.S. market sectors suggests that the FF5 better explains the variation compared to the FF3 model, particularly in small-cap, high-investment portfolios and among highly profitable companies. However, the FF5 model also shows that the role of the HML is reduced in certain contexts, reflecting the ability of the new factors to account for market anomalies and partially replace traditional factors.

The valuation model applies significantly different in global markets and regional markets. Study shows that RMW and CMA factors in FF5 do not have significant explanatory power on expected return in the Chinese A-share stock market (Jiao & Lilti, 2017). In tracking the performance of FF3 and FF5 from July 2010 to May 2015, the paper indicates the distinguishable difference of the Size-B/P portfolio intercept from zero (Jiao & Lilti, 2017). Under the assumption where the coefficients (betas) of the factors explaining the cross-sectional expected return, the intercept β should equal zero. The non-zero intercept thus reveals that FF5 Model do not fully account for the expected return. The researchers also indicated that coefficient of RMW only have statistically significant in Size-OP portfolio and that the coefficient of CMA negatively correlate with small size-aggressive investment portfolio (Jiao & Lilti, 2017). Noticeably, the adjusted R^2 of FF5 and FF3 after running time-series regression on the same portfolio do not differ dramatically. Probability and investment thus do not have explanatory effect on the expected return and the two models' performance do not have huge difference. The result diverges from the empirical study of FF3 and FF5 on the US market where FF5 have higher cumulative return and R^2.

The difference between the two empirical study results on FF3 and FF5 performance reveal the limitation of Fama-French Model in specific regions or context. Whereas the additional two factors of CMA and RMW have improved performance in North America, CMA seems redundant in Europe and Japan (Fama & French, 2016). The studies highlight the importance of market-specific empirical testing and suggest that asset pricing models may require customization or adjustments when applied to different economic and regulatory environments.

3.2 Limitations and Prospects

As an empirical model, FF5 has limitations to measurement of expected return. FF5 model has shown inconsistent performance across different markets, highlighting its limitations in capturing local market dynamics. While the model performs well in the U.S. market, where it significantly improves upon the FF3 model, its effectiveness is less pronounced in other markets, such as the Chinese A-share market and Japanese markets.

Recent research has begun to explore the integration of the FF5 model with advanced technologies and additional factors to improve its predictive capacity. For example, Mita and Takahashi (2023) propose a new approach that combines the FF5 model with artificial intelligence techniques, such as Gradient Boosting Machine (GBM) and state-space models, to enhance the accuracy of return predictions. By using AI-driven predictions in conjunction with the FF5 factors, this approach can dynamically adjust to changing market conditions and better forecast future returns, outperforming traditional strategies like buy-and-hold or typical mutual fund approaches for Japanese equities. The study demonstrates that an AI-enhanced FF5 model not only retains the strengths of the traditional model but also provides superior performance, suggesting a promising future direction for integrating machine learning techniques into asset pricing models to handle large datasets and capture complex patterns in financial markets (Mita & Takahashi, 2024).

As AI and machine learning techniques continue to advance, there is a significant opportunity to enhance the FF5 model's predictive power and applicability across diverse markets. AI-based models have the advantage of processing vast amounts of data more efficiently and identifying complex, non-linear relationships that traditional econometric models may miss. By leveraging these technologies, the FF5 model can potentially evolve into a more flexible and adaptive tool for predicting returns in real-time, accounting for rapid changes in market conditions and investor behavior (Mita & Takahashi, 2024).

Other researchers have explored the addition of new factors to the FF5 model to address its current limitations. Dhaoui and Bensalah expanded the FF5 model by incorporating momentum and investor sentiment factors, arguing that these additions could improve the model's ability to capture certain market behaviors that the standard FF5 model misses. The inclusion of a momentum factor helps account for the tendency of stocks to continue moving in their current direction, while the investor sentiment factor reflects the impact of psychological biases on asset prices. Their findings suggest that this enhanced model can better predict expected returns and explain anomalies related to small stocks with high investment and low profitability, i.e., an area where the original FF5 model often falls short. This approach underscores the potential for further developments that incorporate behavioral and sentiment-based factors, offering a more holistic view of asset pricing that includes both traditional financial variables and behavioral elements (Dhaoui & Bensalah, 2016).

4 CONCLUSIONS

To sum up, FF3 model marked a significant departure from the traditional CAPM by additional factors, which allowed for a more nuanced understanding of stock returns by accounting for systematic risks beyond market exposure. FF5 model represents a further evolution in asset pricing by adding two additional factors to provide a more comprehensive model for understanding the variations in stock returns. Empirical evidence suggests that FF5 generally performs better than FF3 in explaining returns, particularly in markets like the United States. The model's performance varies significantly across different markets. This study recognizes the explanatory limitation of FF5 as empirical model and suggest that the emergence of AI or factor that customized to local financial market will improve the performance of factors. In conclusion, while FF5 represents a substantial step forward in asset pricing theory, its mixed empirical results and inherent limitations indicate that it is not yet the final word on modelling stock returns. Future developments should focus on refining the model by integrating new techniques and data sources to enhance its robustness, flexibility, and applicability across global financial markets.

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