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FAMA-FRENCH THREE-FACTOR ASSET PRICING MODEL IN BORSA ISTANBUL: EXCHANGE INCLUDING TWO ADDITIONAL FACTORS IN THE MODEL[1]

Muhammad MUDDASIR [*]

Asst. Prof. Gülşah KULALI (Ph.D.) [**]

This paper first examines the validity of the Fama-French three-factor asset pricing model (FF3F) in the Borsa Istanbul (BIST). Subsequently, the model's validity is demonstrated, and two additional factors—trading volume and exchange rate—are incorporated in conjunction with the conventional factors employed in the FF3F model: market risk, size, and value. This is achieved by utilizing daily data from 70 listed firms included in the highly representative BIST-100 index from January 2010 to December 2019. The regression estimations indicate that the FF3F model is a valid representation of the BIST, both before and after the inclusion of additional factors. We demonstrate that it effectively captures the risk-return dynamics for market portfolios in the BIST. Furthermore, we show that incorporating trading volume and exchange rate factors enhances the model's accuracy.

Keywords: *Fama-French Three-factor Asset Pricing Model, Emerging and Developing Markets, Borsa Istanbul, Trading Volume, Exchange Rate.*

JEL Codes: *G10, G11, G12.*

1.INTRODUCTION

The development of asset pricing models has been a central focus of modern finance, especially during the period referred to as the "modern finance revolution." In traditional asset pricing theory, markets are considered efficient when there are no frictions—*such as taxes, illiquidity, or transaction costs*—allowing for swift and cost-effective execution of trades (Endri et al., 2020). The efficiency of liquid markets plays a crucial role in this context, as they allow for the smooth transfer of assets between investors. However, as financial markets evolved, several anomalies began to challenge the assumptions of early models like the Capital Asset Pricing Model (CAPM), developed by Sharpe (1964) and Lintner (1965), which sought to explain the relationship between risk and return. Despite its foundational status, CAPM's limitations became evident as numerous empirical tests revealed inconsistencies, particularly

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[*] MA; student of MSc in Economics, University of Pisa, Sant'Anna School of Advanced Studies, Italy, m.muddasir@studenti.unipi.it

[**] Corresponding author, Anadolu University, Faculty of Economics and Administrative Sciences, Türkiye, gulsahy@anadolu.edu.tr.

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the discovery of variables that could not be explained by the model—*referred to as anomalies* (Fama and French, 2008).

In response to these shortcomings, alternative models were developed to explain the behavior of asset prices better. The most prominent among these is the Fama-French Three-Factor Model (FF3F), which augmented CAPM by introducing two additional factors: size (market capitalization) and value (book-to-market equity). Fama and French (1992) demonstrated that these factors significantly improved the model's ability to explain the distribution of average stock returns, suggesting that smaller firms tend to generate higher returns—*called the size effect*— (also see Banz, 1981) and that firms with high book-to-market ratios (value stocks) tend to outperform those with low ratios. Subsequent research, such as Titman et al. (2004), showed that firms raising capital tend to experience negative risk-adjusted returns, and Novy-Marx (2013) found a positive relationship between profitability and expected returns. These developments have prompted a closer examination of asset pricing models to evaluate their ability to account for risk-return relationships, especially when incorporating additional variables.

The FF3F model gained significant attention after demonstrating superior performance to CAPM over a sample of U.S. stocks from 1963 to 1990 (Fama and French, 1993). The model effectively captured the relationship between risk and return, with regressions that included a market factor (beta) and proxies for size and value, resulting in statistically insignificant intercepts. This indicated that the three-factor model could explain the distribution of average stock returns more accurately than CAPM. However, as financial markets have evolved and new empirical data emerged, further extensions of the FF3F have been developed. For example, Carhart (1997) introduced a four-factor model that added a momentum factor to account for the observed persistence in stock returns. Moreover, recent studies have shown that even the FF3F model does not fully capture certain variations in market returns, particularly those related to investment and profitability. More recently, Fama and French (2015) expanded on their earlier work by introducing a Five-Factor Model (FF5F), which added profitability and investment factors to the original FF3F. This model has been shown to better capture the variation in stock returns by including statistically significant variables like operating profitability, investment, and size. Notwithstanding these developments, inconsistencies remain, and the pursuit of a comprehensive asset pricing model continues.

Building on these foundations, this study aims to achieve two objectives. First, it seeks to evaluate the performance and validity of the FF3F model in the context of BIST, an emerging market characterized by low liquidity, inexperienced market participants, and concentration of trading in a few dominant firms. Second, it aims to extend the traditional FF3F model by incorporating two additional variables: trading volume and the exchange rate. These factors are crucial in emerging markets like Turkey, where liquidity constraints and currency volatility play a significant role in determining asset prices. By adding these two variables, we propose a more comprehensive Five-Factor Model (FF5F) that considers these two market-specific factors as well as market risk.

We aim to fill the gap in the literature concerning these unsolved challenges of liquidity constraints and currency volatility for emerging markets. Trading volume is particularly an important measure of market liquidity, which is a key determinant of market efficiency. Higher trading volume indicates greater investor interest and a more effective distribution of assets among market participants (Abbondante, 2010). Conversely, lower trading volume may signal reduced investor engagement and less free float in the market, potentially leading to increased return volatility and higher portfolio risk. Therefore, incorporating trading volume into the asset pricing model allows for a more nuanced understanding of the risk-return relationship in capital markets with liquidity constraints such as emerging markets. Similarly, the exchange rate plays a crucial role in emerging markets like Turkey, where currency fluctuations can significantly impact firm profitability and stock returns. Therefore, it is essential to test whether these two factors have significant impact on the expected portfolio return.

We contribute to the existing literature by assessing the expected portfolio returns of firms listed on BIST using the FF3F model, with portfolios categorized by size (market capitalization) and value (book-to-market equity). By introducing trading volume and exchange rate as additional factors, we seek to investigate whether these variables provide further explanatory power for asset returns in the Turkish market. All in all, the principal objective of the study is to assess the interrelationship between anticipated returns and the variables incorporated in the FF3F model. Additionally, the study endeavors to elucidate the influence of trading volume and exchange rate on portfolio returns. In particular, we aim to determine whether these factors can help measure risk more accurately in an emerging market setting, where liquidity issues and currency volatility are significant concerns. In conclusion, this study seeks to advance the understanding of asset pricing in emerging markets by first testing the validity of the traditional FF3F model and, second, extending and challenging this model by incorporating two additional variables. This study also contributes to the ongoing search for a comprehensive asset pricing model that can better capture the complexities of modern emerging financial markets. In conclusion, the findings of this study provide invaluable insights for financial managers and investors, enhancing their ability to evaluate the relationship between risk and return in their strategic decision-making processes This, in turn, helps them make well-informed decisions to optimize their gains.

2. LITERATURE REVIEW

This section delves into the validity of the CAPM and the FF3F Model, as well as the additional factors incorporated into the FF3F Model. Numerous studies have investigated the validity of asset pricing models across various financial markets. While some studies have reported significant results for Turkish capital market (e.g., Kaya, 2021; Acaravci and Karaomer, 2017; Erdinç, 2017; Kara, 2016; Eraslan, 2013), others have not (Zeren et al., 2019; Ozkan, 2018). Appendix Table A.1 presents a summary of the empirical literature. It can be generalized that the FF3F model is significant in developed markets (Güler et al., 2018). However, there is only limited evidence regarding the validity of such models in the Turkish financial market. This study aims to fill this research gap by providing empirical evidence on two key issues: 1) the validity of the FF3F model in the Turkish financial market, and 2) the inclusion of foreign exchange risk and trading volume factors into the FF3F model to assess the validity of the Intertemporal Capital Asset Pricing Model (ICAPM) in Turkey. Additionally, the study compares both models to determine which yields more robust results. The broader literature on asset pricing, particularly the Fama and French models, offers critical insights into global stock returns, with the FF5F model (Fama & French, 2015) enhancing the FF3F by incorporating profitability and investment factors. Although the FF5F model has demonstrated superior explanatory power in U.S. stock exchanges, residual anomalies persist, raising questions about its applicability in emerging markets such as Turkey.

The Fama-French models have been rigorously tested in the Turkish stock market, particularly in the BIST. Kaya (2021) tested the BIST-100 index over the period 2005 to 2017 using the CAPM, FF3F, and FF5F models. Kaya's findings showed that the FF5F model was better in explaining stock returns, outperforming both the FF3F and CAPM. It suggests that profitability and investment factors are particularly relevant in Turkey, where market structures and investor behaviors differ from those in developed economies. Supporting Kaya's conclusions, Acaravci and Karaomer (2017) analyzed data from 2005 to 2016 on the BIST and confirmed the superiority of the FF5F model. Their research showed that by including size and value factors, the FF5F model was better at capturing Turkish stock returns than previous models. Taken together, these studies highlight the growing acceptance of the FF5F model in explaining stock returns in emerging markets such as Turkey, which reflects the robustness of the model beyond the developed world. In a further exploration of the Turkish market, Erdinç (2017) tested the FF5F model using data from 2000 to 2017. The results demonstrated that the FF5F model outperformed both the FF3F model and the CAPM. Erdinç's study shows that the FF5F model consistently provides better explanatory power over various periods. This consistency across studies reinforces the relevance of the FF5F model for capturing stock returns in emerging markets like Turkey, where additional factors such as profitability and investment are critical in explaining returns.

However, the applicability of the FF5F model is not without limitations. Zeren et al. (2019) tested the model on the BIST Sustainability Index from 1995 to 2017 and found that the FF5F model did not effectively capture stock returns for sustainability-focused companies. This suggests that certain market niches, such as firms in sustainability index, may require different factors beyond those included in the FF5F model, highlighting the model's limitations in specific contexts.

Sectoral analysis has also provided valuable insights into how the FF models perform in different parts of the economy. Kara (2016) applied the FF3F model to the BIST Financials, Services, and Industrials indexes using panel data analysis from 2006 to 2014. Kara's results showed that the size, market risk premium, and book-to-market (B/M) ratio were significant in explaining equity risk premiums across different sectors. While Kara's study did not encompass the FF5F model, the efficacy of the FF3F in sectoral settings implies that the incorporation of additional factors into the FF5F model may facilitate a more profound comprehension of sector-specific stock returns.

Global research on the Fama-French models demonstrates their adaptability across markets. Michou and Zhou (2016), for example, analyzed the London Stock Exchange (LSE) from 1900 to 2013, highlighting the influence of exchange rates on the size and value factors in the FF5F model. This finding is particularly relevant for emerging markets like Turkey, where currency fluctuations are frequent. Similarly, Erdinç (2017) found that the FF5F model outperformed both the FF3F and CAPM in capturing exchange rate effects on the Borsa İstanbul (BIST). Ozkan (2018) further confirmed that the FF5F model's value factor plays a crucial role in explaining returns on the BIST, with exchange rates serving as a significant determinant.

Turning to trading volume, incorporating this factor into asset pricing models has gained interest in the recent literature. In their examination of the BIST from 2005 to 2017, Güler et al. (2018) found that while the FF5F model demonstrated superior performance relative to other models, trading volume exerted a significant influence on stock returns, particularly during periods of market volatility. Similarly, Eraslan (2013) observed that the explanatory power of the FF3F model diminished when trading volumes fluctuated, indicating that external market dynamics, such as liquidity, affect the model's performance.

To enhance comprehension of asset pricing models, Doğan et al. (2022) employed the FF6F model, which incorporates a momentum factor, in an investigation of the BIST between the years 2014 and 2018. Their findings showed that the momentum factor improved the model's ability to explain stock returns, particularly in high-volatility sectors. This suggests that additional factors, such as momentum, could further enhance the FF5F model's explanatory power in markets like Turkey.

The adaptability of the Fama-French models is further supported by research conducted in other emerging markets. Ali et al. (2021) tested the FF5F model on the Pakistan Stock Exchange (PSX) and found that the profitability factor was highly sensitive to exchange rates, reinforcing the need to account for currency volatility in emerging markets. Paliienko et al. (2020) also confirmed the FF5F model's effectiveness on the Ukrainian Stock Exchange between 2014 and 2019, particularly in markets with significant exchange rate volatility.

Most recent research has explored the possibility of developing Fama-French (FF) models. For instance, Zhao (2023) expanded the FF framework for cryptocurrency trading and proposed multi-factor models involving long-short strategies. This approach not only improves predictive accuracy but is also in line with the growing demand for advanced asset pricing tools in emerging markets. In addition, Naffa & Fain (2022) used pure factor portfolios to analyze ESG, governance, and lag leaders and found no significant relationship. Kumar (2023) conducted a comprehensive review of 30 studies that showed mixed results regarding the relationship between ESG and portfolio returns. For example, Zhou & Zhou

(2021) found that companies with a high ESG rating perform better in developed markets than companies with a low rating, which is due to regional and geographical distortions. In addition, Shanaev & Ghimire (2022) examined the interaction between the ratings of ESG and stock returns and concluded that changes in the ratings affect market reactions differently between regions.

In conclusion, while the Fama and French models have been accepted to be a robust framework for explaining stock returns in various markets, they are not without limitations. A review of studies conducted in the Turkish market, including those by Kaya (2021), Acaravci and Karaomer (2017), and Erdinç (2017), consistently demonstrates that the FF5F model outperforms both the FF3F and the CAPM. However, research by Zeren et al. (2019) and Doğan et al. (2022) suggests that factors such as trading volume, exchange rates, and sectoral differences may significantly influence stock returns, pointing to the need for ongoing refinement of these models. Extensions like the inclusion of momentum or human capital, as explored in other studies, may further improve the model's explanatory power in diverse market environments — *see, for example,* Sunarsih (2020), Ali et al. (2021) and Roy and Shijin (2018), *among others*—. The ongoing evolution of the Fama-French models ensures their continued relevance in understanding the complexities of global and emerging financial markets. Studies by Kumar (2023), Naffa & Fain (2022), and Shanaev & Ghimire (2022) highlight that beyond traditional financial factors, new non-financial factors such as ESG and technical indicators play a crucial role in asset pricing for future research.

3. DATA AND METHODOLOGY

Empirically, our study aims to address two key objectives. Firstly, we seek to determine the significance of the FF3F model by examining the relationship between excess return ($E_r - R_f$), risk premium ($R_m - R_f$), size factor (SMB), and value premium (HML). In general, the presence of a positive or negative relationship between risk premium and excess return suggests the model's relevance in predicting market trends, whether bullish or bearish. However, the relationship obtained from the established model aims to determine the effect of risk premium, size factor, and value premium on company returns in this study. Secondly, we investigate whether the FF3F model can be extended to incorporate two additional factors: the exchange rate and the trading volume.

3.1. Data

The daily dataset for this study is derived from 70 publicly listed firms on the BIST-100 index, which represents the main index of BIST, covering the period from January 2010 to December 2019. The Thomson Reuters Database serves as the primary source for stock prices, financial statements, trading volume, and market returns. Additionally, exchange rate data is incorporated, also from Thomson Reuters Database. The data is recorded at a daily frequency, offering a comprehensive 10-year overview of market activity. The initial sample included 100 firms from the BIST-100 index;

however, 30 firms were excluded due to missing data.[2] The final sample comprises 70 firms after removing companies without available data.

Consistent with Fama and French (1993), firms with negative book-to-market equity (BE/ME) values as of December of year k−1 were excluded from the sample for the period spanning from July of year k to June of year k+1. These firms were reintegrated into the sample when their BE/ME values returned to positive levels in subsequent years.

The study employs the Ordinary Least Squares (OLS) regression method to assess the validity of the Fama-French Three-Factor Model (FF3F) and, subsequently, tests the efficacy of an extended Five-Factor Model (FF5F) by incorporating two additional variables: exchange rate and trading volume. The five key variables in the FF3F model are the market returns (proxied by the BIST index), the risk-free rate (Rf), the firm stock prices of BIST-listed companies, High Minus Low (HML), and Small Minus Big (SMB). In the extended FF5F model, exchange rate and trading volume are added to assess whether the inclusion of these factors enhances the FF3F Model's explanatory power.

This study employs the implicit risk-free interest rate to quantify the risk-free rate, in accordance with the approaches of Bianconi et al. (2015) and Black and Scholes (1973). The former group utilized the implicit interest rate as a proxy in option pricing, while the latter established the foundations of modern option pricing models. The implied risk-free rate is derived from the difference between future and spot interest rates. Other studies have employed different proxies for the risk-free rate in Turkish markets. In their studies, Çebi (2012) and Kaya (2021) have utilized the overnight interest rate, while Kara (2016) has applied the 365-day T-bill rate. Eraslan (2013) has employed both quarterly and bi-annual T-bill rates, while Erdinç (2017) has opted for the 3-month Turkish Lira Interbank Offer Rate (TRLIBOR). Gökgöz (2007) has also employed the Monthly Turkish Government Internal Loan Index (GIL). This study's use of the implied interest rate, rather than more traditional ones, reflects a nuanced approach to capturing risk-free returns in the Turkish financial market, aligning with international best practices while addressing local market characteristics.

Compensation for taking on higher risk than T-bills or other government bonds is determined by the other half of the FF3F formula, which involves analyzing the historical returns of the asset compared to those of the market and the market premium ($R_m + R_f$) using a risk measure (beta). For estimating market capitalization (as size factor), we use leverage ratio, and for estimating value premium, we use book-to-market ratio.

Pre-tests are frequently carried out in time series analysis to evaluate the features of the data and choose the best modeling strategy. These pre-tests give information on the underlying structure of the

[2] These excluded companies, such as Alfa Solar Enerji Sanayi ve Ticaret, Biotrend Çevre ve Enerji Yatırımları, Europen Endüstri İnşaat Sanayi ve Ticaret, and Galata Wind Enerji, were all recent additions to the Borsa İstanbul post-2020, and thus lacked the necessary historical data.

time series and check that the assumptions of the chosen model are true. Pre-tests that are frequently used in time series analysis are the stationarity test, normality test, homoscedasticity test, and multicollinearity test. For stationarity, Appendix Tables A.2-A.4 present Augmented Dickey-Fuller test statistics for FF3F Portfolio, FF4F Portfolio, and Independent Variables, respectively. All independent variable p-values and portfolio p-values confirm that our data are stationary. For normality, Appendix Tables A.5-A.7 present Jarque-Bera test statistics for the FF3F Portfolio, FF4F Portfolio, and Independent Variables, respectively. The normality assumption of the residuals is frequently tested in regression analysis using the Jarque-Bera test (Nobre and Singer, 2007). The p-values indicate that our data is normally distributed. For homoscedasticity, Appendix Tables A.8-A.9 present Breusch-Pagan test statistics for the FF3F Portfolio with FX-rate and FF4F Portfolio with FX-rate, respectively. The p-values show that it is safe to utilize our data since it is homoscedastic for all models in FF3F and FF4F with exchange rates. Lastly, the potential multicollinearity was investigated by considering the correlation matrix for the variables that explain the results (Çürük, 2001). Appendix Tables A.10-A.13 present the correlation matrices for independent variables for FF3F and then FF3F with FX-Rate, as well as for FF4F, respectively. The correlation matrix demonstrates that there is no multicollinearity after adding the FX rate to the FF4F model. Reddy et al. (2010) claim that a correlation coefficient of less than 0.5 may be acceptable in real-world situations. All coefficients in Table A.10-13 confirm that there is no multicollinearity in the data and allow us to move on to the regression analysis.

3.2. Portfolio Formation

Market risk, size premium, and value premium are the three risk factors used in the FF3F model. On one hand, the companies were first ranked and sorted into three groups based on their book-to-market (B/M) ratios, labeling the bottom 30% as Low (L), the middle 40% as Medium (M), and the top 30% as High (H), to construct the book-to-market portfolio (Liu et al., 2019). Stocks with low, medium, and high book-to-market ratios in time (t) are categorized into the bottom group, middle group, and top group, respectively, in time (t+1). Stocks were evaluated according to their market capitalization to create a size-based portfolio. On the other hand, the top 50% of the stocks are classified as Big (B), and the bottom 50% as Small (S) (Abd-Alla and Sobh, 2020). Stocks with a large market capitalization at a time (t) are regarded as large stocks at a time (t+1), whilst companies with a modest market capitalization at a time (t) are regarded as tiny stocks at a time (t+1). Tables 1 and 2 present the information about the categorization framework for portfolio construction for FF3F and FF4F, respectively. Appendix Tables A.14 and A.15 present the yearly composition of portfolios by size and book-to-market ratios for FF3F and FF4F, respectively.

The formation of six equally weighted size and book-to-market sorted portfolios yielded the following results: B/H, B/M, B/L, S/H, S/M, and S/L. B/H and other respective portfolios, including all stocks with high book-to-market values and market capitalizations. There were six portfolios in each model. Hence, regression tests were conducted on each model to assess the validity of the FF3F model.

Table 1. FF3F Categorization Framework for Portfolio Construction Based on Size and Value

SIZE	VALUE	PORTFOLIO
B	H	B/H (Big/High)
B	M	B/M (Big/Medium)
B	L	B/L (Big/Low)
S	H	S/H (Small/High)
S	M	S/M (Small/ Medium)
S	L	S/L (Small/Low)

Then, we include trading volume, the fourth factor, in our portfolio. Equities were divided into two groups—the top 50% as High Trading Volume (HV) and the bottom 50% as Low Trading Volume (LV)—to create a trading volume-sorted portfolio (Lee and Swaminathan, 2000). Stocks with high trading volumes at one point in time are referred to as high-volume stocks at that point in time (t+1), and stocks with low trading volumes at that point in time are referred to as low-volume stocks at that point in time (t+1).

In this manner, 12 portfolios with equal weights for size, book-to-market ratio, and trading volume are created: BHHV, BHLV, BMHV, BMLV, BLHV, BLLV, SHHV, SHLV, SLHV, SLLV, SMLV and SMHV. BHHV and the other 11 portfolios cover all the equities with high book-to-market values, market capitalizations, and trading volumes. After confirming the FF3F model's validity, we introduced a new factor, trading volume. Since each model contains 12 portfolios, regression tests for each model were conducted 12 times.

Table 2. FF4F Categorization Framework for Portfolio Construction Based on Size, Value, and Trading Volume

SIZE	VALUE	TRADING VOLUME	PORTFOLIO
B	H	HV	BHHV (Big/High/High Volume)
B	M	HV	BMHV (Big/Medium/High Volume)
B	L	HV	BLHV (Big/Low/High Volume)
B	H	LV	BHLV (Big/High/Low Volume)
B	M	LV	BMLV (Big/Medium/Low Volume)
B	L	LV	BLLV (Big/Low /Low Volume)
S	H	HV	SHHV (Small/High/High Volume)
S	M	HV	SMHV (Small/Medium/High Volume)
S	L	HV	SLHV (Small/Low/High Volume)

S	H	LV	SHLV (Small/High/Low Volume)
S	M	LV	SMLV (Small/Medium/Low Volume)
S	L	LV	SLLV (Small/Low/Low Volume)

The excess portfolio return, which is denoted by ER_i, is the dependent variable in the Fama and French three-component model. The portfolio return demonstrates the return on a portfolio that is higher than the risk-free rate of return needed by investors to support the investors' exposure to risk. A portfolio's return is also weighted based on the performance of all the equities in the portfolio.

Market risk premium, value premium, and size premium are the independent variables in the three-factor model proposed by Fama and French. The FF3F model equation is as follows:

$$R_p = R_f + \beta_1 SMB + \beta_2 HML + \beta_3 (R_m - R_f) \quad (1)$$

where,

R_p = average market return on the portfolio
R_f = risk-free rate of return
R_m = market return
SMB = proxy for size factor
HML = proxy for value premium

Due to their lack of financial flexibility and lack of diversification, small-sized companies are more vulnerable to the adverse effects of various risk factors related to their line of work, giving rise to the concept of size premium, which is necessary for investors to make investment decisions (Hahn and Lee, 2006). Therefore, size premium is a risk factor that investors must consider when making investment decisions (Laborda et al., 2016). The size premium is calculated using the book-to-market ratio (Gerald et al., 1997). A high book-to-market ratio indicates that a stock's book value is higher than its market value. This suggests that the market will not place a high value on the stock due to the market's distress and investors' expectations regarding the stock's ability to generate future profits predictably (Donnelly, 2014).

Trading volume is another risk factor for price and returns in the FF4F model. When there is no price discrepancy between stocks, as shown by high trading volume (Karpoff, 1987), there will not be any increase in stock price; nevertheless, when there is such, as shown by low trading volume, there will be an increase in stock price.

For the FF5F model, the FX rate is used as the last independent variable, and the currency pair USD/TRY is employed for 10 years. The FF3F model equation with the addition of the two new factors is as follows:

$$R_p - R_f = \beta_0 + \beta_1 SMB + \beta_2 HML + \beta_3 (R_m - R_f) + \beta_4 (HVMLV) + \beta_5 (Fx\ Rate) + \mu \quad (2)$$

where,

R_p= average market return on the portfolio.

R_f= risk-free rate of return

R_m= market return

SMB = proxy for size factor

HML = proxy for value premium

HVMLV = proxy for trading volume

FX rate = exchange rate (USD/TRY)

In the Fama-French Three-Factor Model, the beta coefficient (β_0) quantifies systematic risk by measuring a stock's sensitivity to market movements. However, Clarke et al. (2014) argue that beta alone provides an incomplete view of stock performance, as it ignores other crucial return factors, such as size and value, which are incorporated into the FF3F model. Additionally, a company's performance is influenced by the macroeconomic environment of the country in which it operates. In the economically and financially globalized business life, many companies have expanded their operations internationally, further complicating the relationship between domestic and global market factors (Zahra et al., 2000).

4. MODEL ESTIMATIONS

In this section, we outline the study's hypothesis and display all the computations for the variables.

4.1. Daily Portfolio Returns and Market Return

The following formula is used to determine the daily historical returns on a particular stock of i (Marquering and Verbeek, 2004):

$$R_{i,t} = \left(\frac{P_{i,t} - P_{i,t-1}}{P_{i,t-1}}\right) * 100 \quad (3)$$

where $R_{i,t}$ = i^{th} daily return on i^{th} stock at time t; $P_{i,t}$ = the closing price of i^{th} stock at time t; $P_{i,t-1}$ = the closing price of i^{th} stock at time t-1.

The value-weighted average return, which is the portfolio return, is calculated using the following formulation.

$$R_{p,t} = \sum_{i=1}^{N} W_t R_{i,t} \quad (4)$$

Similarly, the market return can be estimated as:

$$R_{m,t} = \left(\frac{M_t - M_{m,t-1}}{M_{t-1}}\right) * 100 \tag{5}$$

where M_t = closing index value at time t; M_{t-1}=closing index value at time t-1.

The estimated value of excess portfolio return (R_p– R_f ~~Rpt-RF~~) and a market risk premium ($R_m - R_f$ ~~Rmt-Rf~~) can be computed by using portfolio and market return (Shalaei, 2017).

4.2. SMB (Small Minus Big) for Fama & French three-factor Model

SMBs take into account the business size-related risk factor (Plastira, 2017; Gharghori et al., 2007). It is calculated as the average portfolio return for a small firm size minus the average portfolio return for a large business size (book to market).

$$SMB = \frac{1}{3}(SH + SM + SL) - \frac{1}{3}(BH + BM + BL) \tag{6}$$

4.3. HML (High minus Low) for Fama & French three-factor Model

HML is a risk component associated with value premiums (Drew and Veeraraghavan, 2002). It is calculated by subtracting the average return of a portfolio of growth stocks with a low book-to-market value from the average return of a portfolio of high book-to-market value firms or value stocks. It is made to be neutral in size.

$$HML = \frac{1}{2}(SH + BH) - \frac{1}{2}(SL + BL) \tag{7}$$

4.4. SMB (Small Minus Big) for Fama & French four-factor Model

SMBs take into account the business size-related risk factor (Leite et al., 2020). It is calculated using trading volume and neutral value (book to market) and is equal to the average return on a portfolio of small firm size minus the average return on a portfolio of big firm size (Opuodho et al., 2018).

$$SMB = \frac{1}{6}(SHHV + SHLV + SLHV + SLLV + SMHV + SMLV) - \frac{1}{6}(BHHV + BHLV + BLHV + BLLV + BMHV + BMLV) \tag{8}$$

4.5. HML (High minus Low) for Fama & French Four-factor Model

HML is a risk component associated with value premiums (Qadan and Jacob, 2022). It is calculated by subtracting the average return of a portfolio of growth stocks with a low book-to-market value from the average return of a portfolio of high book-to-market value firms or value stocks (Opuodho et al., 2018). It is made to be neutral in size and trading volume.

$$HML = \frac{1}{4}(BHHV + BHLV + SHHV + SHLV4) - \frac{1}{4}(+BLHV + BLLV + SLHV + SLLV) \tag{9}$$

4.6. HVMLV (High Volume minus Low Volume)

HVMLV is the difference between the average return of a portfolio of high trading volume and the average return of a portfolio of low trading volume (Chandrapala, 2011).

$$HVMLV = \frac{1}{6}(BHHV + BLHV + BMHV + SHHV + SLHV + SMHV) \; - \frac{1}{6}(BHLV + BLLV + BMLV + SHLV + SLLV + SMLV) \tag{10}$$

Table 3 displays the empirical findings from six portfolios that have been categorized by size and book-to-market equity using individual Fama and French regressions. Market beta (β_0) and significance (at a 1% threshold of significance) were found in this regression for all six portfolios. For each portfolio with large and small companies, the risk factor (β_1) market risk premium has all positive and significant coefficients at the 1% level of significance. The risk factor (β_2) SMB (small minus big) is significant at the 1% level of significance for all portfolios with large-size companies, showing negative coefficients in contrast to the market and positive coefficients for all the portfolios with small-size companies. This difference confirms the existence of a size premium.

For all six portfolios, which contain companies with low, medium, and high book-to-market equity ratios, the value premium of HML (high minus low) is significant at the 1% level of significance. Even though the other portfolios with low coefficients indicate a negative trend, in this case, all portfolios are still significant. This constitutes compelling evidence that the existence of the value premium exerts an influence on the market portfolio.

The estimated fitted values of six portfolios have more than 80% goodness of fit, which shows that the Fama and French 3-factor model explains very much in BIST-100, similar to other studies (Kaya, 2021; Acaravci and Karaomer, 2017; Erdinç, 2017; Kara, 2016; Eraslan, 2013).

Table 4 presents the empirical results for the individual Fama and French 3-factor model with FX-rate as an additional factor. Regressions on six portfolios that are sorted based on size and book-to-market equity. The results are similar to those of Table 3, that all portfolios with all three factors have significant effects on the market. Additionally, SMB and HML confirm that size and value play important roles. Lastly, the fourth factor we added is the FX rate, which is significant and negative at a 1% level of significance for all portfolios. The estimated fitted values of portfolios have more than 80% goodness of fit, and we can see that after adding the exchange rate in the FF3F model, it increases the efficiency of the model by around 3%, which shows that the FF3F model with exchange rate in explain, more than the conventional FF3F model in BIST-100 of Turkish capital market.

Table 3: Estimation Results of FF3F Model in BIST-100

$$R_p - R_f = \beta_0 + \beta_1(R_m - R_f) + \beta_2 SMB + \beta_3 HML + \mu$$

Portfolio	β_0	β_1	β_2	β_3	Adjusted R-square	F-value
SL	-0.677*** (0.000)	0.806*** (0.000)	0.966*** (0.000)	-0.766*** (0.000)	0.861	5166.650
SM	-0.726*** (0.000)	0.795*** (0.000)	0.798*** (0.000)	-0.277*** (0.000)	0.823	3885.879
SH	-0.895*** (0.000)	0.752*** (0.000)	0.897*** (0.000)	0.277*** (0.000)	0.827	3990.650
BL	-0.851*** (0.000)	0.764*** (0.000)	-0.162*** (0.000)	-0.732*** (0.000)	0.805	3451.497
BM	-0.814*** (0.000)	0.771*** (0.000)	-0.082*** (0.000)	-0.258*** (0.000)	0.811	3593.027
BH	-0.633*** (0.000)	0.818*** (0.000)	-0.094*** (0.000)	0.224*** (0.000)	0.875	5880.910

Note: '*,',','**', and '***' represents significance at 10%, 5%, and 1%, respectively. Probabilities are provided in parentheses.

Table 5 presents the empirical result of the individual Fama and French with trading volume regressions on twelve portfolios that are sorted based on size, book-to-market equity, and trading volume. In this regression, market beta (β_0) the coefficients are significant (at a 1% level of significance) for all portfolios. The risk factor (β_1) has all positive and significant coefficients at a 1% level of significance for all portfolios with big and small-size companies. The risk factor (β_2) SMB (small minus big) is significant at a 1% level of significance for all portfolios with big-size companies, showing negative coefficients in contrast with the market, and there are positive coefficients for all portfolios with small-size companies. This difference indicates an existence of size premium. The risk factor (β_3) of HML (high minus low) is significant at a 1% level of significance for all twelve portfolios that include companies with low, medium, and high book-to-market equity. Here, the portfolios with high book-to-market show a positive trend while the other portfolios with ow have negative coefficients, but all six portfolios are significant. This is a clear indication that the value premium has significant effects on the market portfolio.

Table 4. Estimation Results of FF3F Model with FX-rate in BIST-100

$$R_p - R_f = \beta 0 + \beta_1(R_m - R_f) + \beta_2\, SMB + \beta_3\, HML + \beta_4\,(Fx\ Rate) + \mu$$

Portfolio	β_0	β_1	β_2	β_3	β_4	Adjusted R-square	F-value
SL	-0.119*** (0.001)	0.700*** (0.000)	0.963*** (0.000)	-0.678*** (0.000)	-0.334*** (0.000)	0.886	4896.975
SM	-0.136*** (0.001)	0.683*** (0.000)	0.796*** (0.000)	-0.185*** (0.000)	-0.353*** (0.000)	0.851	3590.711
SH	-0.196*** (0.000)	0.619*** (0.000)	0.894*** (0.000)	0.387*** (0.000)	-0.418*** (0.000)	0.866	4048.904
BL	-0.199*** (0.000)	0.640*** (0.000)	-0.165*** (0.000)	-0.631*** (0.000)	-0.391*** (0.000)	0.844	3392.162
BM	-0.131*** (0.001)	0.641*** (0.000)	-0.085*** (0.001)	-0.151*** (0.000)	-0.409*** (0.000)	0.852	3626.200
BH	-0.121*** (0.001)	0.721*** (0.000)	-0.096*** (0.000)	0.304*** (0.000)	-0.306*** (0.000)	0.895	5380.067

Note: '*','**', and '***' represents significance at 10%, 5%, and 1%, respectively. Probabilities are provided in parentheses.

The risk factor (β_4) of HVMLV (high volume minus low volume) is significant and negative at 1% level of significance for six out of six portfolios with low trading volume and three out of six that include companies with high trading volume, two portfolios with high trading volume show significance at 5% and the other at 10%. At the same time, there is a portfolio SMHV, which is insignificant, but all high-volume trade portfolios are positive. It indicates a pattern where trading volume affects market sentiments.

The estimated fitted values of portfolios are more than 65% goodness of fit, which shows that the FF3F model with trading volume is explained in BIST-100. There is no evidence from previous literature in BIST related to Fama and French with trading volume, but our results prove that trading volume has a significant effect in explaining portfolio returns. Similar to this, Opuodho et al. (2018) discovered that in the Nairobi stock market, trading volume does enhance the FF3F Model's value.

Table 6 presents the empirical result of the individual Fama and French with trading volume and exchange rate regressions on twelve portfolios that are sorted based on size, book-to-market equity, and trading volume. In this regression, market beta (β_0) the coefficients are negative and significant (at a 1% level of significance) for ten portfolios, while one portfolio is significant at 10%, and there is a portfolio named SLHV, which is insignificant. The risk factor (β_1) has all positive and significant coefficients at 1% level of significance for all 12 portfolios with big and small-size companies. The risk factor (β_2) SMB (small minus big) is significant at 1% level of significance for all portfolios with big-size companies showing negative coefficients in contrast with the market, and there are positive coefficients for all portfolios with small-size companies, and this difference indicates the existence of size premium. The risk factor (β_3) of HML (high minus low) is significant at a 1% level of significance for eleven portfolios that include companies with low, medium, and high book-to-market equity except one, which is BMHV. Here, the portfolios with high values show a positive trend, while the other portfolios with low have negative coefficients. However, all six portfolios are significant. This is a clear indication that the existence of a value premium has significant effects on the market portfolio. The risk factor (β_4) of HVMLV (high volume minus low volume) is significant and negative at 1% level of significance for six out of six portfolios with low trading volume and five out of six that include companies with high trading volume, except one portfolio which was insignificant in the previous model but this time it shows significance at 5% level. Furthermore, all high-volume trade portfolios are positive. This creates a pattern in which trading volume affects market sentiments. Lastly, the fifth factor we added is the FX rate (with coefficient β_5) is significant and negative at 1% level of significance for all six portfolios. This indicates that the exchange rate risk negatively impacts the Turkish stock market.

The estimated fitted values of portfolios are more than 65% goodness of fitness, which shows that the FF3F model with trading volume and exchange rate explains BIST-100.

Table 5. Estimation Results of FF4F Model in BIST-100

$$R_p - R_f = \beta_0 + \beta_1(R_m - R_f) + \beta_2\, SMB + \beta_3\, HML + \beta_4\,(HVMLV) + \mu$$

Portfolio	β_0	β_1	β_2	β_3	β_4	Adjusted R-square	F-value
SLLV	-0.760*** (0.000)	0.778*** (0.000)	0.668*** (0.000)	-0.442*** (0.000)	-0.929*** (0.000)	0.792	2389.741
SLHV	-0.773*** (0.000)	0.783*** (0.000)	1.164*** (0.000)	-1.086*** (0.000)	0.562*** (0.000)	0.729	1693.564
SMLV	-0.757*** (0.000)	0.781*** (0.000)	0.560*** (0.000)	-0.203*** (0.000)	-0.649*** (0.000)	0.789	2353.751
SMHV	-0.790*** (0.000)	0.769*** (0.000)	0.732*** (0.000)	0.094*** (0.002)	-0.042 0.295	0.741	1800.806
SHLV	-0.822*** (0.000)	0.769*** (0.000)	0.981*** (0.000)	0.288*** (0.000)	-0.799*** (0.000)	0.772	2125.053
SHHV	-0.926*** (0.000)	0.741*** (0.000)	0.654*** (0.000)	0.367*** (0.000)	0.161*** (0.000)	0.780	2232.855
BLLV	-0.824*** (0.000)	0.768*** (0.000)	-0.119*** (0.000)	-0.582*** (0.000)	-0.799*** (0.000)	0.781	2242.329

BLHV	-0.911*** (0.000)	0.742*** (0.000)	-0.455*** (0.000)	-0.618*** (0.000)	0.076* (0.079)	0.682	1350.549
BMLV	-0.848*** (0.000)	0.760*** (0.000)	-0.084*** (0.008)	-0.306*** (0.000)	-0.591*** (0.000)	0.764	2036.707
BMHV	-0.726*** (0.000)	0.790*** (0.000)	-0.205*** (0.000)	-0.091*** (0.000)	0.070** (0.038)	0.797	2468.347
BHLV	-0.817*** (0.000)	0.764*** (0.000)	-0.247*** (0.000)	0.263*** (0.000)	-0.930*** (0.000)	0.654	1188.625
BHHV	-0.702*** (0.000)	0.796*** (0.000)	-0.131*** (0.000)	0.353*** (0.000)	0.477*** (0.000)	0.818	2830.444

Note: '*','**', and '***' represents significance at 10%, 5%, and 1%, respectively. Probabilities are provided in parentheses.

Table 6. Estimation Results of FF4F Model with FX-rate in BIST-100

$$R_p - R_f = \beta_0 + \beta_1(R_m - R_f) + \beta_2 SMB + \beta_3 HML + \beta_4 (HVMLV) + \beta_5 (Fx\ Rate) + \mu$$

Portfolio	β_0	β_1	β_2	β_3	β_4	β_5	Adjusted R-square	F-value
SLLV	-0.170*** (0.000)	0.663*** (0.000)	0.674*** (0.000)	-0.368*** (0.000)	-0.801*** (0.000)	-0.358*** (0.000)	0.821	2302
SLHV	-0.088 (0.210)	0.651*** (0.000)	1.172*** (0.000)	-1.001*** (0.000)	0.710*** (0.000)	-0.416*** (0.000)	0.752	1526
SMLV	-0.145*** (0.002)	0.662*** (0.000)	0.567*** (0.000)	-0.126*** (0.000)	-0.517*** (0.000)	-0.372*** (0.000)	0.820	2295
SMHV	-0.195*** (0.000)	0.653*** (0.000)	0.738*** (0.000)	0.169*** (0.000)	0.087** (0.000)	-0.362*** (0.000)	0.767	1656
SHLV	-0.150*** (0.000)	0.639*** (0.000)	0.988*** (0.000)	0.372*** (0.000)	-0.654*** (0.000)	-0.408*** (0.000)	0.804	2064
SHHV	-0.240*** (0.000)	0.608*** (0.000)	0.661*** (0.000)	0.453*** (0.000)	0.310*** (0.000)	-0.417*** (0.000)	0.817	2244
BLLV	-0.181*** (0.000)	0.643*** (0.000)	-0.112*** (0.000)	-0.502*** (0.000)	-0.660*** (0.000)	-0.390*** (0.000)	0.818	2261
BLHV	-0.242*** (0.000)	0.612*** (0.000)	-0.448*** (0.000)	-0.534*** (0.000)	0.220*** (0.000)	-0.406*** (0.000)	0.718	1278
BMLV	-0.142*** (0.002)	0.623*** (0.000)	-0.076*** (0.008)	-0.218*** (0.000)	-0.438*** (0.000)	-0.429*** (0.000)	0.809	2124
BMHV	-0.134*** (0.004)	0.675*** (0.000)	-0.199*** (0.000)	-0.017 (0.457)	0.198*** (0.000)	-0.360*** (0.000)	0.826	2378
BHLV	-0.201*** (0.004)	0.645*** (0.000)	-0.240*** (0.000)	0.340*** (0.000)	-0.796*** (0.000)	-0.374*** (0.000)	0.678	1059

BHHV	-0.090* (0.051)	0.678*** (0.000)	-0.124*** (0.000)	0.429*** (0.000)	0.609*** (0.000)	-0.372*** (0.000)	0.846	2750

Note: '*','**', and '***' represents significance at 10%, 5%, and 1%, respectively. Probabilities are provided in parentheses.

5. CONCLUSION

The Fama-French three-factor asset pricing model attempts to explain stock market returns in terms of market risk, value, and size. Although the model was initially built using data from US markets, it has since been tested and used in other markets all over the world. According to evidence from relevant literature, the FF3F model can be used to analyze stock market returns in emerging and developed markets. However, depending on the particular market and period, the model's performance may change. In developed markets, the model has often been useful in translating the cross-sectional volatility in stock returns. Studies have discovered, for instance, that the model helps explain stock returns in markets like Canada, the UK, Japan, and several European nations. In emerging markets, the evidence is mixed. Some studies have found that the F&F model is less effective in explaining stock returns in these markets, while others have found that the model performs reasonably well. In some cases, modifications to the original model have been proposed to capture the specific characteristics of emerging markets better.

There are two objectives of this study. The first is to check the validity of the FF3F model in the Borsa İstanbul (BIST). The second is to add two new factors *—namely, trading volume and exchange rate—* and check whether there is any translation in the market in terms of these two factors or not.

The analysis of this study for FF3F model results is in line with the previous research that confirms the validity of the FF3F model in BIST. Also, we can conclude that both size and value are significant and explain portfolio returns in BIST-100 efficiently. Moreover, we first analyze the significance of trading volume on the Borsa İstanbul (BIST). Out of the 12 portfolios, 11 show statistical significance at the 1% level, with the exception of the Small-Medium-High Value (SMHV) portfolio, which does not exhibit significant results. This indicates that, in general, trading volume has a notable impact on portfolio returns. Specifically, companies listed on the BIST 100 index with low trading volumes tend to explain more of the variation in portfolio returns compared to those with high trading volumes. Trading volume, which measures the number of shares traded in each period, can be a reasonable indicator of liquidity. Higher trading volume is often associated with greater market liquidity and improved market information, which in turn may contribute to higher expected returns. Furthermore, the exchange rate, as an additional factor, proves to be significant when incorporated into the FF3F model across all six portfolios. Similarly, the model that includes trading volume maintains its consistency across all 12 portfolios. This suggests that the exchange rate plays a critical role in emerging markets like Turkey, where it can significantly affect market performance. Changes in exchange rates can influence the returns of companies operating internationally, as they may experience increased costs/benefits due to fluctuations in currency values. However, the impact of exchange rates on stock returns is complex and may vary depending on factors such as the specific countries and currencies involved.

While the inclusion of trading volume and exchange rate as additional factors in the FF3F model is a topic of ongoing research and debate, only some studies have found evidence to support their inclusion. However, it is important to note that the performance of any model that includes these additional factors is likely to depend on the specific market and period being examined, and further research is needed to understand their impact on stock returns fully. We reached the conclusion that FF3F is explaining the market portfolios in BIST efficiently, and adding the factors of trading volume and exchange rate enhances the model's accuracy.

Trading volume and the exchange rate are pivotal in emerging markets like Turkey, where liquidity constraints and currency volatility significantly influence asset prices. To address these market-specific factors, we propose a more comprehensive Five-Factor Model (FF5F) that incorporates these two variables alongside market risk. Our objective is to assess whether these factors enhance the accuracy of risk measurement in an emerging market context, where liquidity issues and currency volatility pose substantial challenges. The practical implications of this study are profound, providing valuable insights for financial managers and investors. By gaining a deeper understanding of the relationship between risk and return, they can refine their strategic decision-making processes, leading to more informed choices that optimize their gains.

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KATKI ORANI / *CONTRIBUTION RATE*	**AÇIKLAMA / *EXPLANATION***	**KATKIDA BULUNANLAR / *CONTRIBUTORS***
Fikir veya Kavram / *Idea or Notion*	Araştırma hipotezini veya fikrini oluşturmak / *Form the research hypothesis or idea*	Muhammad MUDDASIR Asst. Prof. Gülşah KULALI (Ph.D.)
Tasarım / *Design*	Yöntemi, ölçeği ve deseni tasarlamak / *Designing method, scale and pattern*	Muhammad MUDDASIR Asst. Prof. Gülşah KULALI (Ph.D.)
Veri Toplama ve İşleme / *Data Collecting and Processing*	Verileri toplamak, düzenlenmek ve raporlamak / *Collecting, organizing and reporting data*	Muhammad MUDDASIR Asst. Prof. Gülşah KULALI (Ph.D.)
Tartışma ve Yorum / *Discussion and Interpretation*	Bulguların değerlendirilmesinde ve sonuçlandırılmasında sorumluluk almak / *Taking responsibility in evaluating and finalizing the findings*	Muhammad MUDDASIR Asst. Prof. Gülşah KULALI (Ph.D.)
Literatür Taraması / *Literature Review*	Çalışma için gerekli literatürü taramak / *Review the literature required for the study*	Muhammad MUDDASIR Asst. Prof. Gülşah KULALI (Ph.D.)

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APPENDIX

Table A.1. Summary of Empirical Literature Review

Authors (Year published)	Sample Period	Market/Index	Tested Model	Key Results
Kaya (2021)	(2005 -2017)	BIST 100 index	CAPM FF3F Model FF5F Model	Even though all three models are valid, FF5F is the model that performs the best overall, followed by FF3F and CAPM, in that order.
Acaravci and Karaomer (2017)	(2005- 2016)	Istanbul Stock Exchange	FF5F Model	FF5F is valid in ISE in accordance with its findings.
Erdinç (2017)	(2000- 2017)	Istanbul Stock Exchange	CAPM FF3F Model FF5F Model	The FF5F Model performs the best, according to the results, followed by the FF3F Model, and finally, CAPM has no ability to explain excess return.
Kara (2016)	(2006- 2014)	BIST Financials indexes, BIST Services, and BIST Industrials,	FF3F Model	Market portfolio risk premiums, business size, and the M/B value ratio all contributed to the explanation of the industrial sector's overall equity risk premium.
Zeren et al. (2019)	(1995- 2017)	ISE Sustainability Index	FF5F Model	There is no evidence supporting the validity of the FF5F Model for Turkish companies. It is vital to keep in mind that this research only focuses on a specific set of companies in Turkey and may not be generalizable to other countries or regions.
Eraslan (2013)	(2003- 2010)	Istanbul Stock Exchange	FF3F Model	The FF3F model can explain changes in excess portfolio returns, but its ability to do so has not been consistently strong over the course of the ISE test period.
Mollaahmetoğlu (2020)	(2009- 2018)	BIST30 index	FF5F Model	In contrast to the FF5F model, they find sufficient empirical evidence for BIST30 to suggest that the four-factor model is valid.
Gökgöz (2007)	(2001- 2006)	Istanbul Stock Exchange	CAPM FF3F Model	On the ISE, CAPM and the FF3F Model are found to be viable and applicable. Pricing errors are handled better by the FF3F Model than by the CAPM.
Roy and Shijin (2018)	(1986- 2016)	NYSE, AMEX, and NASDAQ	Fama-French Six-Factor Model	The human capital component of the framework has the same ability to anticipate fluctuations in return on portfolios as the other framework elements.
Maeda (2016)	Empirical review	Japanese Stock Market (JPX)	CAPM Carhart Four-factor Model FF3F Model FF5F Model	CAPM is an inappropriate model for the JPX. For the Japanese stock market, he contends, the FF3F model is suitable. In order to apply the asset pricing model to the JPX, the book to market factor should be incorporated because the results will be better and the correlation between B/M and share return is significant.

Michou & Zhou (2016)	(1900- 2013)	London Stock Exchange	FF5F Model	Size and value are independent of London stock market returns. For better results, they recommended substituting investment and profitability variables.
Hou et al. (2015)	(2000- 2010)	Japanese stock market (JPX)	Carhart Four-factor Model	FF3F model cannot explain the majority of abnormalities. The Japanese stock market's share returns are not fully explained by the q-factor model, according to the regression results on the portfolio that were classified based on factor size, investment, and profitability. Nonetheless, French and Fama deliver the intended outcomes.
			FF3F Model	
			FF5F Model	
Fama and French (2015)	(1963- 2013)	NYSE, AMEX, and NASDAQ stocks	FF3F Model	On Chinese A-share stock, they employed the FF5F model and contrast it to the FF3F model. The findings demonstrate that the FF3F model best represents the volatility in estimated stock return than the profitability and investment variables.
			FF5F Model	
Khuu et al. (2017)	(2003-2014)	Japanese Stock market	FF3F Model	There is a link between news sentiment and the risk factors for F&F. Additionally, in contrast to middle stocks, where sentiments have little impact on risk factors related to value, small and large stocks tend to be most affected by news sentiments.
Srivastava and Aggarwal (2014)	(2012-2013)	Bombay Stock market	FF3F Model	There is a sizable discrepancy between expected return and actual return, leading researchers to draw the conclusion that the FF3F Model's high volatility between actual and expected return makes it impossible for investors to rely on it.
Nh et al. (2015)	(2007- 2015)	Vietnam Stock Exchange	CAPM	Compared to the FF3F model and CAPM, the FF5F model explains more anomalies in asset pricing. Additionally, state ownership and stock return are correlated with the value factor, with state ownership providing higher average returns than private firms.
			FF3F Model	
			FF5F Model	
Bereket (2014)	(2004- 2013)	Istanbul Stock Exchange	FF4F Model	FF4M is valid in ISE but does not provide a significant performance increase compared to the FF3F model. By investing in various assets with weak correlation coefficients, investors can take advantage of diversification.
Guzeldere and Sarioglu (2012)	(1999-2011)	Istanbul Stock Exchange	FF3F Model	The FF3F model is effective in explaining stock returns in ISE, they discovered. It was also determined that the conventional CAPM, which states that a financial asset's risk premium is positively correlated with its market risk, is valid.
Hasan et al, (2017)	(2005-2010)	Kuala Lumpur Stock Exchange Market (KLSE)	FF3F Model	CAPM and FF3F models can both be used to explain excess returns in the KLSE market. Nonetheless, the FF3F model outperforms the CAPM in terms of explanatory power.

Ozkan (2018)	(2006-2016)	Istanbul Stock Exchange	FF5F Model	Findings demonstrate the applicability of the FF5F model to ISE. In ISE, it is discovered that Value is an essential factor in estimating stock market returns. Consequently, it may be said that the value element in the FF5F model is not unnecessary. This result confirms earlier research showing the value component has a significant role in determining stock returns.
Paliienko et al, (2020)	(2014-2019)	Ukrainian Stock Exchange	FF5F Model	FF5F model fits Ukrainian stock returns better than the FF3F model.
Albakri (2023)	(2017-2021)	S&P 500 Index	FF4F Model	The CAPM is seen as desirable as compared to FF4F in the scope of the desirability of the S&P 500 stock markets because it provides compelling and conceptually appealing estimates on how to evaluate uncertainty and the relationship between expected earnings and dangers.
Sunarsih (2020)	(2014-2018)	Indonesia Sharia Stock Index (ISSI)	FF5F Model and Momentum factor	Investors can examine Islamic stock portfolios listed in ISSI using the FF5F model.
Doğan et al. (2022)	(2014-2018)	Istanbul Stock exchange	FF6F Model with Momentum factor	FF6F is the model that best accounts for stock returns on the BIST. The suggestion that momentum be taken into account while making investment because it enables greater profits to be realized is one of the research study's practical recommendations.
Ali et al. (2021)	(2003–2016)	Pakistan Stock exchange (PSX)	FF3F Model	The depiction of average returns is much improved by the profitability component. The results are robust across sub-periods, test asset development, and various factor definitions.
			Carhart Four-factor Model	
			FF5F Model	
			FF6F Model with Momentum factor	
Güler et al. (2018)	(2005–2017)	Istanbul Stock exchange	CAPM	This model has undergone testing in a number of developed nations, most notably it is effective in explaining variances in stock market returns in the US. The study whether this paradigm is applicable to emerging nations with dynamics that are distinct from those of developed nations, however, has certain flaws. It has been found that FF5F outperforms the alternative models in the BIST.
			FF3F Model	
			FF5F Model	
Anghel et al. (2015)	(2006-2013)	Bucharest Stock Exchange	FF3F Model	The FF3F model captures more fluctuation in portfolio returns than the traditional model according to the authors, who also demonstrate that it passes standard diagnostic tests.
Kumar (2023)	Empirical review	Global/Regional Portfolios	FF3F with ESG factor	For globally diversified portfolios, no significant correlation was found between ESG factors and the portfolio. Positive relationships have been observed for regionally diversified portfolios, especially in developed markets. Regional bias is also recorded.
			FF5F with ESG factor	
			FF3F	
			FF5F	

Table A.2: Augmented Dickey-Fuller test statistic for FF3F Portfolio

Portfolios	t stats	P-Value
SH	-3.15844	0.0227
SL	-2.69292	0.0753
SM	-3.02485	0.0328
BH	-3.16601	0.0222
BL	-2.70541	0.0732
BM	-2.96662	0.0383

Table A.3 Augmented Dickey-Fuller test statistic for FF4F Portfolio

Portfolios	t stats	P-Value
BHHV	-3.41352	0.0106
BHLV	-3.64202	0.0051
BLHV	-3.15164	0.0231
BLLV	-2.75916	0.0644
BMHV	-2.57218	0.0989
BMLV	-2.8129	0.0566
SHHV	-3.30871	0.0146
SHLV	-3.57966	0.0063
SLHV	-3.05292	0.0304
SLLV	-2.66379	0.0806
SMHV	-3.39348	0.0113
SMLV	-3.01342	0.0338

Table A.4: Augmented Dickey-Fuller test statistic for Independent Variables

Factors	t stats	P-Value
Rm-Rf	-3.63274	0.0052
SMB	-44.2116	0.0001
HML	-46.5861	0.0001
HVMLV	-47.69	0.0001
Fx-Rate	-2.89667	0.0995

Table A.5: Jarque-Bera test statistics for FF3F Portfolio

Portfolio	Jarque-Bera	Probability
B_H	584.5432	0.269
B_L	887.325	0.387
B_M	796.6815	0.326
S_H	898.0076	0.353
S_L	852.5184	0.348
S_M	940.9334	0.334

Table A.6: Jarque-Bera test statistics for FF4F Portfolio

Portfolio	Jarque-Bera	Probability
BHHV	501.3722	0.250
BHLV	593.1412	0.271
BLHV	586.9938	0.264
BLLV	1036.127	0.408
BMHV	524.4949	0.254
BMLV	832.6083	0.348
SHHV	754.4461	0.312
SHLV	915.695	0.378
SLHV	2198.958	0.893
SLLV	815.0853	0.398
SMHV	774.5212	0.290
SMLV	869.8234	0.323

Table A.7: Jarque-Bera test statistics for Independent Variables

Variables	Jarque-Bera	Probability
RM_RF	1340.832	0.567
SMB	686.7923	0.332
HML	787.5464	0.278
HVMLV	235.251	0.132
FX_RATE	438.3485	0.194

Table A.8: Homoscedasticity test statistic for FF3F Portfolio with Fx-rate

Portfolio	P-Value
B/H	0.169
B/L	0.282
B/M	0.322
S/H	0.153
S/L	0.408
S/M	0.342

Table A.9: Homoscedasticity test statistic for FF4F Portfolio with Fx-rate

Portfolio	P-value
BHHV	0.450
BHLV	0.271
BLHV	0.262
BLLV	0.268
BMHV	0.494
BMLV	0.348
SHHV	0.212
SHLV	0.118
SLHV	0.193
SLLV	0.38
SMHV	0.290
SMLV	0.311

Table A.10: Correlation Matrix of the independent Variables for FF3F

	Rm-Rf	*SMB*	*HML*
Rm-Rf	1		
SMB	-0.04777	1	
HML	0.269115	-0.03229	1

Table A.11: Correlation Matrix of the independent Variables for FF3F with FX-Rate

	Rm-Rf	*SMB*	*HML*	*FX Rate*
Rm-Rf	1			
SMB	-0.04777	1		
HML	0.269115	-0.03229	1	
FX Rate	-0.47021	0.020687	-0.00333	1

Table A.12: Correlation Matrix of the independent Variables for FF4F

	Rm-Rf	*SMB*	*HML*	*HVMLV*
Rm-Rf	1			
SMB	0.024334	1		
HML	0.166715	-0.23871	1	
HVMLV	0.137238	0.27557	-0.32754	1

Table A.13: Correlation Matrix of the independent Variables for FF4F with FX-Rate

	Rm-Rf	*SMB*	*HML*	*HVMLV*	*FX Rate*
Rm-Rf	1				
SMB	0.024334	1			
HML	0.166715	-0.23871	1		
HVMLV	0.137238	0.27557	-0.32754	1	
FX Rate	-0.47021	0.010627	-0.02505	0.050892	1

Table A.14: Number of stocks in FF3F year-wise sample composition of portfolio

Year	Small/Low (S/L)	Small/Medium (S/M)	Small/High (S/H)	Big/Low (B/L)	Big/Medium (B/M)	Big/High (B/H)	Total
2010	11	16	8	9	14	12	70
2011	7	18	10	13	12	10	70
2012	7	18	11	13	12	9	70
2013	8	17	10	12	13	10	70
2014	8	16	11	12	14	9	70
2015	9	18	9	11	12	11	70
2016	10	16	9	10	14	11	70
2017	10	17	8	10	13	12	70
2018	10	16	9	10	14	11	70
2019	11	15	9	9	15	11	70

This table presents the annual composition of portfolios categorized by size and book-to-market factors, detailing the number of stocks allocated to each portfolio from 2010 to 2019.

Table A.15: Number of stocks in FF4F year wise sample composition of portfolio

Year	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**AVG.**
SLLV	9	6	6	7	6	7	8	6	7	8	7
SMLV	10	9	11	10	10	8	9	11	11	10	9.9
SHLV	1	3	4	3	3	3	5	2	3	1	2.8
BLLV	5	8	7	7	8	8	8	7	5	6	6.9
BMLV	9	8	7	7	7	7	4	8	8	9	7.4
BHLV	10	1	1	9	1	2	1	1	1	1	2.8
SLHV	2	1	1	1	2	2	2	4	3	3	2.1
SMHV	6	9	7	7	6	10	7	6	5	5	6.8
SHHV	7	7	7	7	8	6	4	6	6	8	6.6
BLHV	4	5	6	5	4	3	2	3	5	3	4
BMHV	5	4	5	6	7	5	10	5	6	6	5.9
BHHV	2	9	8	1	8	9	10	11	10	10	7.8
Total	70	70	70	70	70	70	70	70	70	70	70

This table presents the annual composition of portfolios categorized by size, book-to-market and trading volume factors, detailing the number of stocks allocated to each portfolio from 2010 to 2019