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Research Article

Testing multi-factor asset pricing models in Borsa Istanbul[1]

Borsa İstanbul'da çok faktörlü varlık fiyatlama modellerinin test edilmesi

Gökhan Özer[2]

Ayşegül Yıldırım Kutbay[3]

[1] This study was derived from the doctoral dissertation on "Testing Multi-Factor Asset Pricing Models" conducted within the PhD in Business Program of the Department of Social Sciences, Gebze Technology Institute.

[2] Prof. Dr., Gebze Technical University Faculty of Business Administration, Gebze, Turkey, ozer@gtu.edu.tr

ORCID: 0000-0002-3255-998X

[3] Lect., Balikesir University, Burhaniye Faculty of Applied Sciences, Balıkesir, Turkey, aysegulyildirim@balikesir.edu.tr

ORCID: 0000-0002-3100-2928

Corresponding Author:

Ayşegül Yıldırım Kutbay

Balikesir University Burhaniye Faculty of Applied Sciences, Balıkesir, Turkey, aysegulyildirim@balikesir.edu.tr

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Abstract

This study aims to test the validity of multi-factor asset pricing models on the portfolios of non-financial companies whose shares are traded on Borsa Istanbul and to identify the model with the best explanatory power. Accordingly, the relationships between annual book-to-market equity ratio, firm size, market portfolio return, return on capital, operating profitability, momentum and value-added intellectual coefficient between 2008-2019 were analyzed using panel data analysis. As a result of the analyses made, it has been observed that Fama French's three and five factors, Carhart (momentum), q-factor, and suggested models are successful in explaining the returns of portfolios formed by non-financial companies. Furthermore, according to the GRS-F test statistic, the q-factor model was found to have higher explanatory power than other models.

Keywords: Factor Models, CAPM, Fama-French, Carhart, Momentum, Q- Factor, Value Added Intellectual Coefficient

Jel Codes: G120, C580, M500

Öz

Bu çalışmanın amacı, çok faktörlü varlık fiyatlama modellerinin Borsa İstanbul'da pay senetleri işlem gören mali sektör dışı firmaların oluşturduğu portföyler üzerinde geçerliliğinin test edilmesi ve en iyi açıklama gücüne sahip modelin belirlenmesidir. Bu kapsamda 2008-2019 tarihleri arasında yıllık defter değeri / piyasa değeri (DD / PD), firma büyüklüğü, pazar portföy getirisi, sermaye karlılığı, faaliyet karlılığı, momentum ve entelektüel Katma Değer Katsayı arasındaki ilişkiler panel veri analiziyle incelenmiştir. Yapılan analizler sonucunda Fama French üç ve beş faktör, Carhart (momentum), q- faktör ve önerilen modeller ile tüm modellerin mali sektör dışı firmaların oluşturduğu portföylerin getirilerinin açıklanmasında başarılı oldukları görülmüştür. GRS-F test istatistiğine göre ise q- faktör modelinin diğer modellere göre yüksek açıklayıcı güce sahip olduğu bulgusuna ulaşılmıştır.

Anahtar Kelimeler: Faktör Modelleri, CAPM, Fama- French, Carhart- Momentum, q- Faktör, Entelektüel Katma Değer Katsayı

JEL Kodları: G120, C580, M500

Introduction

We can define the concept of investment in general terms as transferring a current and specific value to different areas to make profits or increase wealth later. In the financial sense, the concept of investment can be described as the evaluation of a monetary authority or a company in the direction of buying and selling various financial instruments with the assets it holds to make profits (Genç and Çömlekçi, 2018;258). However, it is also possible that the economic benefit from realizing a monetary loss or incurring an expense or loss due to investment is less. In this context, situations such as the peril of making wrong decisions, making a loss, or not making a profit are commonly referred to as "risk" (Bolak, 2004;3). Although many people use risk and uncertainty interchangeably, they are quite different concepts. Risk can be considered a subset of quantifiable or measurable uncertainty (Usta and Demireli, 2010:26). As long as the risk of the investment made under uncertainty can be measured, the opportunity/opportunities are also captured. Until Markowitz's paper (1952;77), securities investors had no idea how to measure some of the risks they were taking. With his published research, Harry Markowitz laid the foundation for modern portfolio theory with his approach to measuring the expected return and risk of the portfolio. Many researchers have further developed the foundations of modern portfolio theory created by this model, and asset pricing models have emerged.

The Efficient Markets Hypothesis states that no investor can earn a higher return than usual with the information available (Fama, 1970). However, there are empirical findings that contradict this hypothesis. According to the literature, the concept of predictability of prominent prices in markets invalidates the assumption of the efficient market hypothesis that "investors cannot earn abnormal returns." This situation, which deviates from the theory, has found its place in the financial literature under the name of "anomaly." The information that risk and return can be calculated and abnormal returns can be obtained as a result has attracted the attention of investors. Moreover, researchers are trying to identify the models that best explain these anomalies and predict returns. From this point of view, this study aims to determine whether the existing asset pricing models in the literature apply to the portfolios of non-financial companies whose shares are traded on Borsa Istanbul and to identify the model that best explains the stock returns.

The results of the study contribute to the literature in several ways. First, this study proposes a seven-factor asset pricing model to understand the risk-return trade-off better and establishes the proposed models' validity. It contributes to the existing literature on the multi-factor asset pricing model. Second, the models we proposed using the value-added intellectual coefficient are significant in Table 8 and Table 10. Therefore, we can say that the VAIC component used in the proposed model is as important as the factors in the literature. Similar results were also found in studies that examined this variable in the literature (Campbell, 1996; Heaton and Lucas, 2000; Lustig, Van Nieuwerburgh and Verdelhan, 2013).

Literature review

Theoretical framework

Markowitz first presented the relationship between the risk of financial investment and its expected return in the model of Modern Portfolio Theory. This theory provides information on the calculation of portfolio risk and portfolio return, portfolio diversification, and the creation of an optimal portfolio.

Sharpe (1964) and Lintner (1964) developed Modern Portfolio Theory and created the Capital Asset Pricing Model (CAPM). This model was presented as a continuation of Markowitz's Modern Portfolio Theory. It can be seen that the asset pricing models developed according to the CAPM emerged as an alternative to the CAPM, which takes into account a single risk factor, and were developed to address the shortcomings of this model. These pricing models are also referred to as *Multi-Factor Asset Pricing Models*. The developed alternative pricing models show more than one risk factor to financial asset returns and how these factors affect returns. The central anomalies that contradict the efficient markets hypothesis and the CAPM's empirical validity are the firm size anomaly, Book-To-Market Equity Ratio anomaly, the price-earnings ratio, and the low price. Fama and French developed the "Three-Factor Asset Pricing Model" (FF3F) as an alternative to the CAPM model (Fama and French, 1995).

A pricing anomaly is based on the theory that abnormal returns can be achieved with a portfolio created by considering the stock's past returns. Price anomalies are divided into two types: Momentum and Overreaction. The momentum anomaly is based on the hypothesis that the past return performance of stocks will be the same in the future. In other words, it predicts that stocks that have performed well in the past will perform well in the future and that stocks that have performed poorly will perform poorly or inadequately. The momentum variable is successful in the long run when combined with other anomalies affecting the company, but not in the short-run (Jegadeesh and Titman, 1993;89-90). The study conducted by Carhart (1997) developed the "Four-Factor Asset Pricing Model (CARHART)", which is based on Fama and French's model and momentum.

A new model has been developed incorporating the investment variable and is an alternative to the Fama-French factor models. The model developed by Hou, Xue, and Zhang (2015;651) is called the *q-factor model*. According to the q-factor model, the expected returns of stocks are estimated by the factors of market factor, firm size, investment, and profitability. The Q-factor model and the Fama-French five-factor model used profitability variables. However, profitability is calculated with many different formulas in the literature. Income statement items such as gross profit, continuing operating profit, operating profit, profit before tax and net profit for the period are used instead of profit. Fama and French (2006:515) stated that profitability measurements deteriorate as you go down the income statement and argue that using gross sales profit or net operating profit would give more accurate results. Therefore, they used the RMW (Net Operating Profit/Equity) variable they created in their study. Similarly, Novy-Marx (2013:2) used the RMW variable in his study for the same reasons. However, Chen, Novy-Marx and Zhang (2011:2) used ROE (Net Profit / Equity) as the profitability variable in their study. Hou, Xue and Zhang (2015: 651) preferred to use ROE to measure the profitability variable in the q-factor model they created.

Studies in the literature have led researchers to believe that some characteristics of the company also have an impact on stock prices. In this context, the value-added intellectual coefficient (VAIC), a firm anomaly, is added to the models developed in the literature to test the validity of these models in all indices (except the financial sector) of Borsa Istanbul. Defining and measuring the concept of intellectual capital is among the relatively difficult and complex issues. At the microeconomic level, "intellectual capital" refers to non-physical (added) sources of value for a company or organization. While these resources are expressed as human capital (e.g. skills, experience, education, etc.), relational capital (e.g. customer and stakeholder relationships, brands, negotiations) and structural capital (e.g. company culture, work environment, systems, intangible rights), they also form the components of intellectual capital at the same time (Ståhle, Ståhle and Aho, 2011:532). These components were first described by Sveiby (1988). Intellectual capital, which many researchers after Sveiby's work have researched, has gained a different dimension with the value creation efficiency analysis of Pulic (2000) and Pulic and Kolakovic (2003). Based on Pulic's other studies on this subject, Ståhle Researched the value-added intellectual coefficient (EKDK) to find out how a "Value Added Intellectual Capital Coefficient (VAIC)" firm relates to its stock market value, return on investment, and returns on assets. Considering the studies on the value-added intellectual coefficient, it is seen that the variable is positively related to the margin rate and return on assets (Nimtrakoon,2015:587) and that it affects the financial performance of the business (Gürkan, Gökbulut and Çolak,2015:45; Meles, Porzio, Sampagnaro and Verdoliva, 2016:64; Dženopoljac, Janoševic and Bontis,2016:373; Smriti and Das,2018:935; Sardo and Serrasqueiro,2017:771; Xu and Liu, 2020:161), having a statistically significant and positive relationship with the market value book value ratio (Odabaşoğlu, 2019:1), having a positive relationship with earnings, profitability and operating efficiency of companies and that it is the most effective value for financial performance, physical and financial capital and human capital (Ekim, Acar and Uçan, 2019:37). Finally, Roy and Shijin (2018;207) argue that the coefficient component of the value-added intellectual coefficient has the same predictive power as other factors in explaining asset returns. This indicates that the value-added intellectual coefficient is essential when modelling asset returns in multi-factor asset pricing models. In addition, the aim is to test all the models in the literature and observe the impact of the value-added intellectual coefficient.

Empirical evidence

In reviewing the literature, it was found that many studies in the national and international literature examine the CAPM, the Fama-French Three-Factor (FF3F), and the Fama-French Five-Factor (FF5F) models. In their study, Fama and French (1998:1975) extended their model to the global context, including the United States and twelve major EAFE countries (Europe, Australia, and the Far East). They found that the FF3F model is a model that better explains stock returns compared to the CAPM. Rehman and Baloch (2016:173) compared the CAPM and FF3F models in their study over 2009-2015 in Pakistan and found that the CAPM performed better than FF3F. The study of Saleh (2020:19) regarding Indonesian markets examined the explanatory power of the CAPM, FF3F, and FF5F models and found that FF3F has higher explanatory power than other factors. Zeren, Yılmaz, and Belke (2018:391) found that the model with the FF5F factor did not work in the context of the Borsa Istanbul Sustainability Index between 1995 and 2017. Güler, Çam, Zavalsız, and Keskin (2018:183) investigated whether FF5F is valid for the Turkish stock market between January 2005 and June 2017 and tested how well FF5F performs compared to other alternative models, especially CAPM and FF3F. The research results show that FF5F outperforms the other alternative models in the Turkish stock market.

Doğan, Elitaş, and Altınay (2019:224) concluded that portfolios of the FF5F model constructed with stocks of small-scale companies have higher explanatory power than portfolios constructed with large-scale companies. Arı and Sarıoğlu (2021:114) find insufficient evidence that the Fama-French Five-Factor Asset Pricing Model is valid at Borsa Istanbul. As can be seen from the studies in the literature, when comparing the CAPM, the FF3F model, and the FF5F model, it appears that the models work in some markets and not others. This situation has led researchers to seek other models. Multi-factor asset pricing models have taken on a new dimension with the research of Jegadeesh and Titman (1993). This study explains the method of calculating the momentum factor and its impact on markets. According to the study, there is a strategy of buying stocks that have performed well in the past and selling stocks that have performed well in the past. It is found that this strategy provides positive returns when it is repeated in specific periods (momentum). In addition to the papers examining the effect of the momentum factor in stock markets, which was introduced in the literature with the study by Jegadeesh and Titman (1993), Carhart (1997: 61-81) developed the four-factor model in his study by combining this factor with the FF3F. According to the study's results, the power of the one-year momentum effect to explain the profitability dimension is better than that of the long-term momentum. In their study covering North America, Europe, Japan, and Asia-Pacific countries, Fama and French (2012:457) found that stock returns based on the momentum factor outperformed other factors. Bildik and Gülay (2007;85) examined the validity of momentum and contrarian investment strategies on ISE (Istanbul Stock Exchange) stocks from 1991 to 2000. The study used Fama-French Three-Factor Model (FF3F) and momentum strategy. According to the results of the analysis, it was found that the contrarian investment strategy is generally more successful than the momentum strategy in periods less than one month and in the long-term periods up to 36 months.

Using the q-factor model, Hou, Xue, and Zhang (2015:651), attempting to explain stock returns with a different variable, presented the model that best explained this relationship in the literature by predicting the expected return on stocks. Fabozzi, Huang, and Wang (2016:28) compared the FF5F model with the q-factor model using monthly data from January 1972 to December 2013. According to the results of the analysis, it was found that the q-factor model was more successful than the FF5F model. Kang, Kang, and Kim (2019:593) analyzed the data formed on the Korean Stock Exchange between July 2002 and June 2015 using the FF5F model and the q-factor model and found that the model best explained the returns on the Korean Stock Exchange was the FF5F model. These discrepant results prompted the researchers to investigate whether there is a better model than the q-factor. In this direction, it appears that the research focuses on firm-specific anomalies. Maiti and Balakrishnan (2018:734) examined intellectual capital (human capital) as the sixth factor. According to the research results, the Intellectual Capital factor significantly improved regression results and model efficiency in both three- and five-factor models. Roy and Shijin (2018:205) tested a six-factor model with the intellectual capital component. The research results show that this six-factor model is more successful than the FF5F model in explaining changes in portfolio returns.

Research method

This section presents the analysis of the variables in the research, the econometric expressions of the models formed by the variables and, the creation of portfolios, the scope of the data set.

Models, variables and hypotheses

The econometric formulas of the models used in the research are as follows:

CAPM model:

$$R_{it} - R_{ft} = \alpha_i + b_i(R_{mt} - R_{ft}) + \varepsilon_{it} \quad (1)$$

Fama-French Three-Factor Model:

$$R_{it} - R_{ft} = \alpha_i + b_i(R_{mt} - R_{ft}) + s_i SMB_t + h_i HML_t + \varepsilon_{it} \quad (2)$$

Carhart (Momentum), Four-Factor model:

$$R_{it} - R_{ft} = \alpha_i + b_i(R_{mt} - R_{ft}) + s_i SMB_t + h_i HML_t + m_i CAR_t + \varepsilon_{it} \quad (3)$$

Fama- French Five-Factor model:

$$R_{it} - R_{ft} = \alpha_i + b_i(R_{mt} - R_{ft}) + s_i SMB_t + h_i HML_t + w_i RMW_t + n_i CMA_t + \varepsilon_{it} \quad (4)$$

Hou, Xue and Zhang's q-factor model:

$$R_{it} - R_{ft} = \alpha_i + b_i(R_{mt} - R_{ft}) + s_i SMB_t + n_i CMA_t + r_i ROE_t + \varepsilon_{it} \quad (5)$$

Proposed models:

$$R_{it} - R_{ft} = \alpha_i + b_i(R_{mt} - R_{ft}) + s_i SMB_t + h_i HML_t + n_i CMA_t + w_i RMW_t + m_i CAR_t + e_i \mathrm{VAIC}_t + \varepsilon_{it} \quad (6)$$

$$R_{it} - R_{ft} = \alpha_i + b_i(R_{mt} - R_{ft}) + s_i SMB_t + h_i HML_t + n_i CMA_t + r_i ROE_t + m_i CAR_t + e_i \mathrm{VAIC}_t + \varepsilon_{it} \quad (7)$$

The meanings and calculation methods of the variables in the formulas are as follows:

R_{mt} : Monthly returns of XUTUM Indice

R_{ft} : The study used monthly nominal yields of government debt securities in return for the risk-free interest rate for this variable.

R_{it}: The expected return on the portfolio

(R_{mt}–R_{ft}): Market risk premium

SMB: The difference in return at time t between portfolios of small and large market capitalization stocks

HML: The difference between the return of the portfolio consisting of shares of companies with a high Book-To-Market Equity Ratio and the return of the portfolio consisting of shares with a low Book-To-Market Equity Ratio.

RMW: The difference between the return of the portfolio consisting of stocks of companies with high profitability value and the return of the portfolio consisting of stocks of companies with low profitability value.

CMA: The difference between the return on the portfolio of stocks of companies with high investment value and the return of stocks of companies with low investment value.

CAR: The difference between the return on the portfolio of stocks of firms with low momentum and the return of stocks of firms with high momentum.

ROE: The difference between the return of the portfolio consisting of high profitability stocks and the return of the portfolio consisting of low profitability stocks.

VAIC: Value Added Intellectual Coefficient of the Firm.

Table 1: Calculation Methods of Variables in Formulas

Variables	The formula needed to calculate the factor
Calculating the RMW factor (Fama and French, 2015:3)	$\frac{Operating\ Profit\ or\ Loss_{t-1}}{Shareholders\ Equity_{t-1}}$
Calculating the CMA factor (Fama and French, 2015:3)	$\frac{Total\ Of\ Assets_{t} - Total\ Of\ Assets_{t-1}}{Total\ Of\ Assets_{t-1}}$
Calculating the CAR factor (Jegadeesh and Titman, 1993:68)	$R_{ij} = \left[\prod_{t=-j}^{-1}((1+r_{it})-1)\right]$ R_{ij} = J-month cumulative return of the stock t= t month J portfolio construction period in the portfolio construction period r_{it}= Return of the Stock in "t" month
Calculating the ROE factor (Hou, Xue, and Zhang, 2015:651)	$\frac{Net\ Profit\ For\ The\ Years_{t}}{Equity\ Capital_{t}}$
Calculating the VAIC factor (Ståhle, Ståhle and Aho, 2011:533-534)	KD: Value Added, KD = FK + IS + A + IP YS= Structural Capital, YS = KD- IS FSE: The coefficient of efficiency of the firm's financial and real capital, FSE = KD / VDD ISE: The firm's human capital efficiency coefficient, ISE = KD / IS YSE: Firm's structural capital efficiency coefficient, YSE = YS / KD **VAIC = FSE + ISE + YSE** The meanings of the variables in the formula are; FK: Operating Profit. IS : Firm total wage and salary expenses. (Direct Labour Expenses + General Administration Expenses + Marketing Sales And Distribution Expenses + Research And Development Expenses). A: Depreciation Expenses. IP: Redemption. VDD= Net Book Value of Assets.

After the variables in Table 1 were calculated for each company, portfolios were constructed. Following the portfolio construction, the averages of these portfolios were taken, and the variables under study were determined using the formulas in Table 2.

Table 2: Creation of Factors

Cut-off Points	Component of Factors
Size : Average Book-To-Market Equity Ratio: 30th and 70th percentiles Profitability (RMW): 30th and 70th percentiles Investment (CMA): 30th and 70th percentiles Momentum(CAR): 30th and 70th percentiles Profitability (ROE): 30th and 70th percentiles Value Added Intellectual Coefficient (VAIC): 30th and 70th percentiles	$SMB_{DD/PD}$= (SH + SN + SL) /3 – (BH + BN + BL) /3 $SMB_{AKâr}$= (SR + SN + SW) /3 – (BR + BN + BW) /3 SMB_{Yat} = (SC + SN + SA) /3 – (BC + BN + BA) /3 SMB_{Mom} =(SP+SQ+SV)/3-(BP+BQ+BV)/3 $SMB_{ÖKar}$=(SG+SJ+SK)/3-(BG+BJ+BK)/3 SMB_{EnSer}=(SD+SE+SF)/3-(BD+BE+BF)/3 SMB=($SMB_{DD/PD}$+ $SMB_{AKâr}$+ SMB_{Yat}+ SMB_{Mom}+ $SMB_{ÖKar}$+ SMB_{EnSer})/6 HML=(SH+BH)/2-(SL+BL)/2 RMW=(SR+BR)/2-(SW+BW)/2 CMA=(SC+BC)/2-(SA+BA)/2 CAR=(SP+BP)/2-(SV+BV)/2 ROE=(SG+BG)/2-(SK+BK)/2 VAIC=(SD+BD)/2-(SF+BF)/2

In Table 2, the calculations of the factors studied in the research are given in the literature framework. Finally, Table 3 shows the hypotheses developed within the research framework.

Table 3: Hypotheses Developed Within the Scope of Research

H_1: The CAPM explains the variation in portfolio returns better than FF3F, Carhart, FF5F, q-factor and the proposed model.
H_2: FF3F explains the variation in portfolio returns better than CAPM, Carhart, FF5F, q-factor, and the proposed model.
H_3: Carhart explains the variation in portfolio returns better than CAPM, FF3F, FF5F, q-factor, and the proposed model.
H_4: FF5F explains the variation in portfolio returns better than CAPM, FF3F, Carhart, q-factor, and the proposed model.
H_5: Q-factor explains the variation in portfolio returns better than CAPM, FF3F, Carhart, FF5F, and the proposed model.
H_6: The first of the proposed models explain the variation in portfolio returns better than CAPM, FF3F, Carhart, FF5F, and q-factor.
H_7: The second proposed model explains the variation in portfolio returns better than CAPM, FF3F, Carhart, FF5F, and the q factor.

Scope of data set and purpose of research

Table 4: Number of Firms Included in the Research by Years

Year	Number of firms	**Year**	Number of firms	**Year**	Number of firms
2008	121	2012	159	2016	180
2009	124	2013	165	2017	181
2010	134	2014	174	2018	185
2011	146	2015	177	2019	-

As of June 2020, 351 companies are publicly traded in the BIST Indexes. The distribution of these companies among the four main indexes is as follows: 164 companies in BIST Industry (XUSIN), 63 companies in BIST Services (XUHIZ), and 19 companies in BIST Technology (XUTEK), and 105 companies in BIST Finance (XUMAL). The research covers 133 monthly data for 2008 June-2019 June and non-financial sector companies publicly traded on the stock exchange. However, some companies were excluded from the scope of the research. The reasons for excluding companies from the scope of the research are that they are companies with a negative PD/DD value in December every year, which started to be traded in the stock market as of 2019. Still, they have published financial data and more than one stock (such as Kardemir and Adana Cement). Table 4 shows the number of companies included in the study by year.

The variables' data were obtained from the Finnet Financial Information News Network, the Public Disclosure Platform, and the Turkish Statistical Institute (TSI). The study used monthly nominal yields of government debt securities in return for the risk-free interest rate. These data were used from the report on the Periodical Real Rate of Return of Financial Investment Instruments by Years published by TURKSTAT. The reason for starting the research in 2008 is that the footnotes of the companies could not be accessed through the platforms Public Disclosure Platform and datastore.borsaistanbul.com. Therefore, the value-added intellectual coefficient, one of the research variables, could not be calculated.

Results

This section presents the findings that emerged from the analysis and attempts to show the similarities with the literature.

Table 5: Descriptive Statistics and Correlation Matrix

Descriptive Statistics	*Portfolio Return*	*R_m-R_f*	*SMB*	*HML*	*CMA*	*ROE*	*RWM*	*CAR*	*VAIC*
Mean	-0.8712457	0.127218	0.003493	0.014451	0.001079	0.016554	0.008778	-0.130514	-0.000416
Standard Deviation	1.918382	5.286658	0.062196	0.087751	0.106145	0.086242	0.100576	0.268275	0.106708
Min	-9.528117	-14.21	-0.1406303	-0.2596538	-0.5253887	-0.4849633	-0.7497951	-2.366951	-0.5174222
Max	7.827294	17.53	0.4660798	0.433081	0.3890966	0.2254129	0.2483587	0.2399537	0.2474021
Number of Observations	4788	4788	4788	4788	4788	4788	4788	4788	4788
									Correlation
Portfolio Return	1.000								
R_m-R_f	-0.0911*	1,0000							
SMB	0.0714*	-0.1125*	1.0000						
HML	0.0078	0.0623*	0.0350	1.0000					
CMA	0.0681*	0.0806*	0.0413***	-0.0623*	1.0000				
ROE	-0.0849*	-0.0025	0.0699*	0.0052	0.2246*	1.0000			
RMW	0.0129	-0.0613*	-0.1159*	0.1375*	-0.1004*	0.3978*	1.0000		
CAR	-0.0450**	0.0963*	-0.4778*	-0.0596*	0.2464*	-0.0127	0.0954*	1.0000	
VAIC	0.0106	0.0158	0.0346	0.0790*	0.3173*	0.1269*	0.0747*	0.2137*	1.0000

*Significant at the 1% level, ** Significant at the 5% level, *** Significant at the 10% level

Table 5 shows the variables' mean, standard deviation, minimum and maximum values, the total number of observations, and the correlation coefficients and significance levels between the variables. Given the table, no correlation coefficient can be regarded as high (0.70 and above) between the dependent and independent variables. This shows that there is no multicollinearity problem between the variables. The table shows a weak and moderate correlation between the variables (Hohlfelder, Sylvester, Rimsans, DeiCicchi and Connors, 2017;500).

Table 6: Unit Root Test Results

Variables	Im-Pesaran-Shin unit-root		LLC		PP Fisher		Decision
	W-t-bar	Prob	Adjusted t	Prob	Adjusted R^2	Prob	
Portfolio return	-33.8838	0.001	-28.8867	0.0001	99.023	0.0001	Stationary
R_m-R_f	-56.0060	0.001	-56.8800	0.0001	208.8018	0.0001	Stationary
SMB	-72.6616	0.001	-76.9962	0.0001	210.2619	0.0001	Stationary.
HML	-68.5115	0.001	-73.0231	0.0001	210.2619	0.0001	Stationary.
CMA	-69.5085	0.001	-74.3683	0.0001	210.2619	0.0001	Stationary.
RMW	-74.3532	0.001	-79.6547	0.0001	210.2619	0.0001	Stationary.
ROE	-74.0331	0.001	-78.2338	0.0001	210.2619	0.0001	Stationary.
CAR	-66.6759	0.001	-70.5042	0.0001	210.2619	0.0001	Stationary.
VAIC	-53.3959	0.001	-56.3951	0.0001	195.6756	0.0001	Stationary.

In order to be able to analyze the variables in econometric models, the variables must have a static data set. If there is non-stationary data in the model, meaningful results can be obtained even if there is no significant relationship between the variables (Gujarati, 2004:741). For this reason, when Table 6. It is seen that Im-Pesaran-Shin Unit-Root, LLC and Fisher-PP unit root tests are tested. Thus, it was desired to test the stationarity of the variables by performing more than one unit root test among them. Given Table 6. the panel data set is stationary and suitable for further analysis.

Table 7: Tests for the Determination of Regression Analysis Model

Models	F(Chow) test		Breusch-Pagan Lagrange Multiplier (LM) Test	
	F- value	Prob> F	Chi-Square test Statistics	Prob> F
(1) ***R_m-R_f(CAPM)***	0.02	0.999	0.00	0.999
(2) ***R_m-R_f SMB***	0.02	0.999	0.00	0.999
(3) ***R_m-R_f SMB HML (FF3F)***	0.02	0.999	0.00	0.999
(4) ***R_m-R_f SMB HML CMA***	0.02	0.999	0.00	0.999
(5) ***R_m-R_f SMB HML CMA RMV(FF5F)***	0.02	0.999	0.00	0.999
(6) ***R_m-R_f SMB HML CAR (Momentum- Carhart)***	0.02	0.999	0.00	0.999
(7) ***Rm-R_f SMB CMA ROE (q-factor)***	0.02	0.999	0.00	0.999
(8) ***R_m-R_f SMB HML CMA CAR ROE***	0.02	0.999	0.00	0.999
(9) ***R_m-R_f SMB HML CMA RMW CAR***	0.02	0.999	0.00	0.999
(10) ***R_m-R_f SMB HML CMA RMW CAR EDKD***	0.02	0.999	0.00	0.999
(11) ***R_m-R_f SMB HML CMA ROE CAR EDKD***	0.02	0.999	0.00	0.999

The F-test was used to test the validity of the classical model (Tatoğlu, 2016;168). Given Tablo 7, there is no unit effect according to the F-test. Therefore, using the classical model instead of the fixed effects model is more appropriate. Breusch-Pagan (1980) developed the Lagrange Multiplier (LM) test statistic, which uses the residuals of the pooled least squares model to test the pooled most miniature squares model (classical model) against the random-effects model of a panel data set (Tatoğlu, 2016;178). In this direction, when Table 7. is examined, it becomes clear that there is no unit effect in the models developed according to the LM test. As a result of the model analysis for the data set, it was determined that it is appropriate to use the pooled least squares estimator.

Table 8: Pooled least squares method and GRS-F test results

R_i-R_f	α_i	b_i	s_i	h_i	n_i	w_i	m_i	r_i	e_i	F-test Statistic	Prob> F	Adjusted R2	GRS-F	
													Test Statistics	A|ai|
(1) R_m-R_f *(CAPM)*	-0.8670266 (-31.39) *	-0.0331647 (-6.33) *								40.02	0.0001	0.0081	985.21315	0.86702658
(2) R_m-R_f *SMB*	-0.8740431 (-31.65) *	-0.0306279 (-5.82) *	1.916607 (4.28) *							29.25	0.0001	0.0117	1001.3117	0.87404314
(3) R_m-R_f *SMB HML (FF3F)*	-0.8774229 (-31.36) *	-0.030895 (-5.85) *	1.902201 (4.25) *	**0.2397105 (0.76)**						19.69	0.0001	0.0116	983.36687	0.87742285
(4) R_m-R_f *SMB HML CMA*	-0.879771 (-31.52) *	-0.0333525 (-6.31) *	1.778226 (3.97) *	**0.3534233 (1.12)**	1.344764 (5.14) *					21.44	0.0001	0.0168	993.61662	0.87977102
(5) R_m-R_f *SMB HML CMA RMV (FF5F)*	-0.8826247 (-31.54) *	-0.0327823 (-6.18) *	1.856853 (4.12) *	**0.2908809 (0.91)**	1.373975 (5.23) *	**0.3848997 (1.37)**				17.53	0.0001	0.0170	994.71209	0.88262469
(6) Rm-Rf SMB HML CAR (Momentum- Carhart)	-0.8851775 (-28.16) *	-0.0307457 (-5.82) *	1.772724 (3.49) *	**0.2307562 (0.73)**	-	**-**	**-0.1177106 (-0.54)**			14.84	0.0001	0.0114	792.9141	0.8851775
(7) Rm-Rf SMB CMA ROE (q-faktör)	-0.8403775 (-29.93) *	-0.0334878 (-6.39) *	2.00546 (4.50) *	-	1.776545 (6.67) *	-	-	-2.492667 (-7.62) *		35.90	0.0001	0.0283	895.59662	**0.83464278**
(8) Rm-Rf SMB HML CMA RMV CAR	-0.9179063 (-28.78) *	-0.0323786 (-6.11) *	1.274297 (2.46) **	**0.2578243 (0.81)**	1.566823 (5.69) *	**0.4410555 (1.56)**	-0.2838133 (-2.30) **			15.50	0.0001	0.0179	827.91022	0.91790632
(9) Rm-Rf SMB HML CMA CAR ROE	-0.8777392 (-27.56) *	-0.0336313 (-6.40) *	1.332298 (2.60) **	**0.3723164 (1.18)**	2.014704 (7.20) *	-	**-0.3110251 (-2.54)**	-2.538856 (-7.76) *		25.31	0.0001	0.0296	759.57364	0.87773918
(10) R_m-R_f *SMB HML CMA RMW CAR EDKD*	-0.9163217 (-28.67) *	-0.0324389 (-6.12) *	1.324968 (2.54) ***	**0.284448 (0.89)**	1.632193 (5.70) *	**0.4619791 (1.63)**	**-0.2647318 (-2.11)**	-	**-0.2347549 (-0.84)**	13.39	0.0001	0.0178	822.11255	0.91632175
(11) R_m-R_f *SMB HML CMA CAR ROE EDKD*	-0.8774035 (-27.50) *	-0.0336499 (-6.40) *	1.342321 (2.60) ***	**0.3786383 (1.20)**	2.027363 (7.03) *	-	**-0.3067386 (-2.46)**	-2.534902 (-7.73) *	**-0.0498245 (-0.18)**	21.69	0.0001	0.0294	756.22262	0.87740354

The fields marked 'bold' in the table indicate the insignificant variables in the Pooled Least Squares Model. Based on the results obtained with the resistive estimators after the bias tests in Table 10, it appears that all other variables are significant, except for one of these non-significant variables (* Significant at 1%, ** Significant at 5%, *** Significant at 10%).

When an asset pricing model explains expected returns well, the return on the portfolio (or stock) exceeds the risk-free rate and alpha coefficients obtained from time-series regressions with factors equal to zero (Fama and French, 2017:450). Instead of measuring whether the alpha coefficients obtained from the time series regressions are individually different from zero, the F-test was proposed by Gibbons, Ross and Shanken(1989:1124) to determine whether they are equal to zero. The model with the lowest alpha coefficient according to the GRS F-Test statistic is the model that best explains the anomalies in the market among the asset pricing models. The above table shows that the q-factor model is the best model for the data set (0.83464278). The β-coefficients in the table show the explanatory power of each variable for the dependent variable. After this phase, tests for deviation of the model assumptions should be performed, and the model with the most accurate estimator should be estimated. This stage aims to determine if assumption deviations exist in the model and estimate the estimator that best eliminates them.

Tablo 9: Tests for Deviation from Model Assumptions

Models	**White's test**		**Wooldridge test**	
	R^2	Prob> F	F statistic	Prob> F
(1) R_m-R_f ***(CAPM)***	127.04	0.001	39815.145	0.0001
(2) R_m-R_f ***SMB***	234.86	0.001	20057.217	0.0001
(3) R_m-R_f ***SMB HML (FF3F)***	384.26	0.001	19013.144	0.0001
(4) R_m-R_f ***SMB HML CMA***	523.95	0.001	19757.669	0.0001
(5) R_m-R_f ***SMB HML CMA RMW (FF5F)***	829.52	0.001	19660.908	0.0001
(6) ***Rm-Rf SMB HML CAR (Momentum- Carhart)***	821.14	0.001	20465.783	0.0001
(7) ***Rm-Rf SMB CMA ROE (q-factor)***	705.84	0.001	21581.302	0.0001
(8) ***Rm-Rf SMB HML CMA RMV CAR***	127.40	0.001	20718.069	0.0001
(9) ***Rm-Rf SMB HML CMA CAR ROE***	1257.13	0.001	20450.995	0.0001
(10) R_m-R_f ***SMB HML CMA RMW CAR VAIC***	1433.70	0.001	23520.413	0.0001
(11) R_m-R_f ***SMB HML CMA ROE CAR VAIC***	1521.09	0.001	22385.577	0.0001

The White test was used to test whether there is a heteroscedasticity problem in the pooled least squares model. Since the R^2 value is significant, our model has a heteroscedasticity problem. Wooldridge (2002) developed this test to examine autocorrelation in panel data models. According to the results of this test, the H_0 hypothesis that belongs to the specific test was rejected in the research and found an autocorrelation problem in the model. Heteroscedasticity is commonly observed in panel data models due to the unit size. In this case, in the pooled least squares model, the assumption that 'the (conditional) covariance between the error terms of different periods in this model is zero, so there is no autocorrelation' is invalid (Tatoğlu, 2016;211). Based on this information, the heteroscedasticity and autocorrelation were determined using the pooled least squares method. Arellano, Froot, and Rogers estimators were used to eliminate these errors and predict the models.

Table 10 shows the results of the Arellano, Froot, and Rogers estimators. Although it provides the same β-coefficients as in Table 8, we see that our insignificant variables become significant in some models when the variances are removed because of the abovementioned deviations. For example, while in Table 8, we can observe that the HML variable represented by the h_i coefficient is insignificant for each model, in Table 10, we can see that it becomes significant when the model is run. Similarly, although it was observed that the Intellectual Capital variable was insignificant in Table 8, it became significant for the tenth model in Table 10.

Table 10: Test results of models with Arellano, Froot and Rogers Resistive estimator

Ri-Rf	α_i	b_i	s_i	h_i	n_i	w_i	m_i	r_i	e_i	F Statistics	Prob> F	R²	Root MSE
(1) R_m-R_f (CAPM)	-0.8670266 (-203.34) *	-0.0331647 (-98.49) *								9699.44	0.0001	0.0083	1.9106
(2) R_m-R_f SMB	-0.8740431 (-222.99) *	-0.0306279 (-96.78) *	1.916607 (10.39) *							5535.92	0.0001	0.0121	1.9072
(3) R_m-R_f SMB HML (FF3F)	-0.8774229 (-229.16) *	-0.030895 (-99.03) *	1.902201 (10.33) *	**0.2397105 (7.07) ***						3836.87	0.0001	0.0122	1.9072
(4) R_m-R_f SMB HML CMA	-0.879771 (-227.40) *	-0.0333525 (-109.81) *	1.778226 (9.57) *	**0.3534233 (10.53) ***	1.344764 (30.25) *					4886.92	0.0001	0.0176	1.9022
(5) R_m-R_f SMB HML CMA RMW (FF5F)	-0.8826247 (-226.50) *	-0.0327823 (-110.57) *	1.856853 (10.10) *	**0.2908809 (8.73) ***	1.373975 (30.53) *	**0.3848997 (10.11) ***				3925.84	0.0001	0.0180	1.902
(6) Rm-Rf SMB HML CAR (Momentum-Carhart)	-0.8851775 (-274.34) *	-0.0307457 (-95.19) *	1.772724 (13.00) *	**0.2307562 (6.91) ***	-	-	**-0.0637269 (-1.47) ***			3625.35	0.0001	0.0123	1.9074
(7) Rm-Rf SMB CMA ROE (q-factor)	-.8346428 (-217.25) *	-0.0334878 (-108.35) *	2.00546 (10.75) *	-	1.776545 (39.69) *	-	-	-2.492667 (-66.23) *		6227.51	0.0001	0.0291	1.891
(8) Rm-Rf SMB HML CMA RMV CAR	-0.9179063 (-289.50) *	-0.0323786 (-104.82) *	1.274297 (9.46) *	**0.2578243 (7.83) ***	1.566823 (44.33) *	**0.4410555 (11.80) ***	-0.2838133 (-6.54) *			3277.94	0.0001	0.0191	1.9012
(9) Rm-Rf SMB HML CMA CAR ROE	-0.8777392 (-284.60) *	-0.0336313 (-107.60) *	1.332298 (9.82) *	**0.3723164 (11.18) ***	2.014704 (57.23) *	-	**-0.3110251 (-7.16) ***	-2.538856 (-66.99) *		4741.44	0.0001	0.0308	1.8898
(10) R_m-R_f SMB HML CMA RMW CAR VAIC	-0.9163217 (-287.46) *	-0.0324389 (-104.78) *	1.324968 (9.90) *	**0.284448 (8.70) ***	1.632193 (46.64) *	**0.4619791 (12.42) ***	**-0.2647318 (-6.07) ***	-	**-0.2347549 (-7.03) ***	2882.91	0.0001	0.0192	1.9012
(11) R_m-R_f SMB HML CMA ROE CAR VAIC	-0.8774035 (-282.83) *	-0.0336499 (-107.37) *	1.342321 (9.94) *	**0.3786383 (11.50) ***	2.027363 (57.84) *	-	**-0.3067386 (-7.01) ***	-2.534902 (-67.05) *	***-0.0498245 (-1.49)***	4084.15	0.0001	0.0308	1.89

*Significant at the 1% level, ** Significant at the 5% level, *** Significant at the 10% level

Table 11: Hypothesis Results

Hypotheses	Accepted	Rejected
H_1: The CAPM explains the variation in portfolio returns better than FF3F, Carhart, FF5F, q-factor and the proposed model.		X
H_2: FF3F explains the variation in portfolio returns better than CAPM, Carhart, FF5F, q-factor, and the proposed model.		X
H_3: Carhart explains the variation in portfolio returns better than CAPM, FF3F, FF5F, q-factor, and the proposed model.		X
H_4: FF5F explains the variation in portfolio returns better than CAPM, FF3F, Carhart, q-factor, and the proposed model.		X
H_5: Q-factor explains the variation in portfolio returns better than CAPM, FF3F, Carhart, FF5F, and the proposed model.	X	
H_6: The first of the proposed models explain the variation in portfolio returns better than CAPM, FF3F, Carhart, FF5F, and q-factor.		X
H_7: The second proposed model explains the variation in portfolio returns better than CAPM, FF3F, Carhart, FF5F, and the q factor.		X

Table 11. shows the results of the hypotheses regarding the research. Accordingly, all the models proposed in the study are valid (Table 11.- Prob <0.001). In this direction, according to the GRS F-test statistic (Table 8.), it was found that the model that best explains the variance in stock returns of the portfolios included in the research is the model of the q-factor (0.83464278). Furthermore, it was observed that the models with the best explanatory power after the q-factor were CAPM (0.86702658), FF3F (0.87742285) and FF5F (0.88262469), respectively.

Conclusion and recommendations

The accurate calculation of expected stock returns has been a notable topic since the 1950s. Multi-factor asset pricing models, which began with the theory of Markowitz (1952), attracted the attention of researchers in the field with the three-factor pricing model developed by Fama and French (1995). The desire to uncover the factors that shape markets and their impact on the expected returns of stocks have led researchers to develop various models. First, Carhart (1997) added the momentum factor to Fama French's model, which Jegadeesh and Titman (1993) proposed in Fama French's study, and made it run on markets. Following this study, the validity of Hou, Xue, and Zhang's (2015) model was tested by adding the profitability variable to Fama French's three-factor model. As a result of all these developments, Fama and French (2015) developed a five-factor asset pricing model in their study. The studies by Chiah, Chai, Zhong, and Li (2016) report that the Fama-French five-factor model outperforms other multi-factor asset pricing models in explaining the variance in returns in global stock markets. All of this research encourages testing the validity of asset pricing models in more markets and finding the model that works in all markets and has the best explanatory power by detecting anomalies that have not yet been explained and incorporating them into the models.

In particular, the effectiveness of all developed and proposed models related to asset pricing in Turkey was investigated. According to the results of the research, it can be said that the q-factor model has the best explanatory power compared to the other models, with a test value of 0.83464278, based on the results of the GFRS-F test (Table 8.). In contrast, all models run in the Borsa Istanbul. Similarly, in his study using the GFRS-F test, Özkan (2019;441) stated that the q-factor model has better explanatory power than other Borsa Istanbul models.

The study suggests better asset pricing models to price stocks and delivers abnormal returns in Borsa Istanbul. Since multi-factor models are widely used in the fund management industry for security selection, portfolio construction, and performance evaluation, the models proposed in the study are expected to impact these practices significantly. The results of this study also provide evidence for commonly used components in multi-factor asset pricing models. Further studies may contribute to the literature by using different tests, different anomalies, and different period lengths on the predictability of Borsa Istanbul Index returns.

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