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Do There Exist Nonlinear Phenomena of the Fama-French Six Factors on Stock Returns?—An Empirical Investigation on the Taiwan Stock Market

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Abstract

This study intends to verify the explanatory power of the Fama-French (2018) six-factor model and to investigate the nonlinear phenomena of the Fama-French six factors on stock returns in the Taiwan region stock market. The timeframe for this study spans from January 2010 to December 2021. The findings indicate that the Fama-French (2018) six-factor model has significant explanatory power on stock returns in the Taiwan region stock market. The influences of the Fama-French six factors vary across different international stock markets. In the Taiwan region stock market, the market risk factor, the size factor, the investment factor, and the momentum factor positively influence on stock returns, while the value factor and the profitability factor exert a negative influence on stock returns. The findings also reveal that the market risk factor, the size factor, the value factor, the profitability factor, and the investment factor exist nonlinear phenomena on stock returns in the Taiwan region stock market when analyzed through panel data regression models.

Keywords

Fama-French Six-Factor Model, Taiwan Region Stock Market, Panel Data Regression Model, Nonlinear

1. Introduction

In 2008, a financial crisis struck, severely impacting economies and stock markets worldwide. However, from 2010 onwards, the global economy saw signs of recovery. As depicted in Figure 1, stock markets in countries such as the United States, the United Kingdom, Germany, Japan, and China, gradually stabilized. In Table 1, Table 2, and Figure 2, "Transaction Values of Listed and OTC Stocks" indicate a significant shift in Taiwan region stock market dynamics. From 2010 to 2016, the number of actual traders fell from 3,317,920 to 2,761,882, marking a 16.76% decrease. Similarly, the trading volume of stocks listed on the market and over-the-counter (OTC) dropped from NT$33.85 trillion in 2010 to NT$21.82 trillion in 2016, a 35.53% decline. Post-2016, both the number of traders and trading volume in Taiwan region stock market has shown a consistent annual increase. By 2021, the number of traders soared to 5,499,558, up 99.12% from 2016, while trading volume escalated to NT$112.56 trillion, increasing by 415.85% from 2016, surpassing the levels observed in 2010.

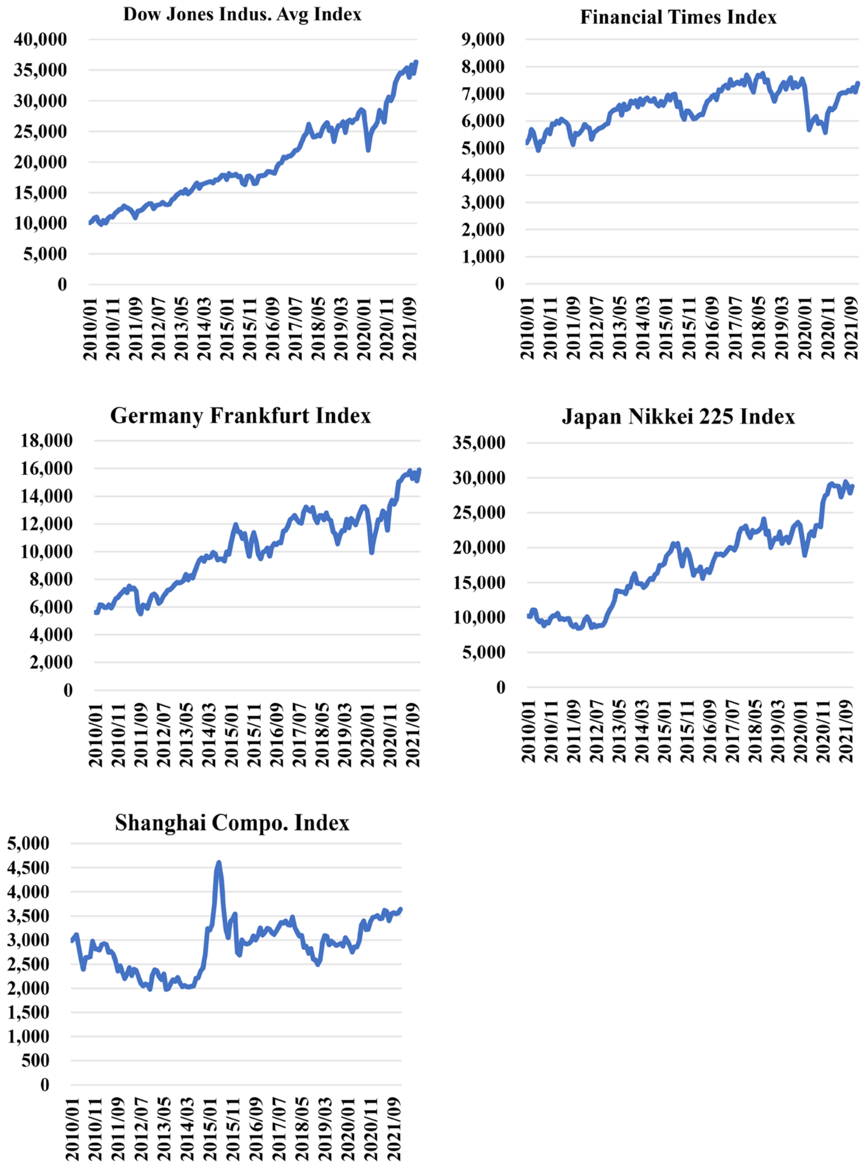

Figure 1. Trend charts of selected international stock markets.

Table 1. Statistics on traders and accounts in the Taiwan region stock market.

Year	No. of actual traders	No. of actual clients
2010	3,317,920	3,836,473
2011	3,362,054	4,031,147
2012	2,954,251	3,678,990
2013	2,952,754	3,436,888
2014	3,027,238	3,484,833
2015	2,887,018	3,267,175
2016	2,761,882	3,153,130
2017	3,124,818	3,585,037
2018	3,260,584	3,687,485
2019	3,342,378	3,799,305
2020	4,378,586	5,048,721
2021	5,499,558	6,463,388

Source: Taiwan region stock exchange.

Table 2. Statistics on trading volume in the Taiwan region stock market.

Year	Trading volume of listed stocks (NT$ million)	Trading volume of over-the-counter stocks (NT$ million)	Total (NT$ million)
2010	28,218,676	5,633,588	33,852,264
2011	26,197,408	3,993,036	30,190,444
2012	20,238,166	2,951,905	23,190,071
2013	18,940,933	4,030,895	22,971,828
2014	21,898,537	6,355,872	28,254,409
2015	20,191,486	5,689,178	25,880,664
2016	16,771,139	5,050,322	21,821,461
2017	23,972,239	7,683,524	31,655,763
2018	29,608,866	8,145,508	37,754,374
2019	26,464,628	7,607,480	34,072,108
2020	45,654,292	12,087,068	57,741,360
2021	92,289,966	20,275,957	112,565,923

Source: Taiwan region stock exchange, Over-the-Counter (OTC).

What are the determinants of stock returns? This question has been central to academic inquiry for decades. Building upon Markowitz's (1952, 1959) foundational work on mean-variance analysis from 1952 and 1959, scholars like Sharpe (1964), Lintner (1965), and Black (1972) introduced the Capital Asset Pricing

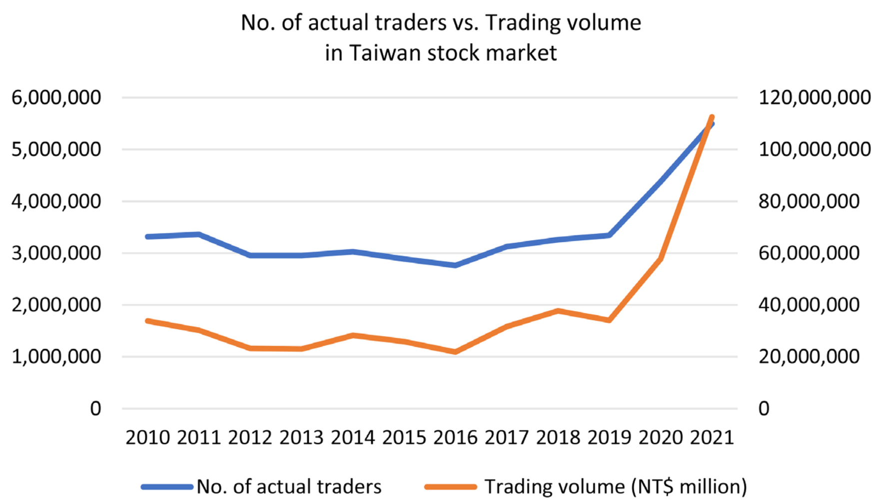

Figure 2. No. of act traders vs. trading vol. in the Taiwan region stock market.

Model (CAPM). This model posits a direct, positive relationship between stock returns and systematic risk, measured by the beta coefficient. However, the CAPM's reliance on assumptions that deviate from real-world conditions—such as the notion of perfect markets and homogeneous expectations—has been a point of contention among researchers. In response, Ross (1976) developed the Arbitrage Pricing Theory (APT), which is predicated on the CAPM framework but incorporates a multi-factor approach. This development has spurred further investigation into the impact of diverse factors on stock returns.

Basu (1977) identified that firms with lower price-to-earnings ratios exhibit superior stock returns compared to those with higher ratios. Further investigations by Stattman (1980), along with Rosenberg, Reid, and Lanstein (1985), established that companies characterized by high book-to-market ratios are typically associated with elevated stock returns. Banz (1981) highlighted the presence of a size effect in the stock market, indicating that smaller companies frequently enjoy higher stock returns. Jegadeesh and Titman (1993) introduced the concept of the momentum effect, positing the existence of price continuation phenomena in stock markets. Their findings demonstrate that firms with higher (or lower) stock returns over the past three to twelve months tend to maintain similar performance trends in the subsequent year.

Based on the foundational theories of the Capital Asset Pricing Model and Arbitrage Pricing Theory, Fama and French (1993) devised a three-factor model. This model suggests that stock returns are influenced not only by the market risk factor but also by the size factor (Small Minus Big, SMB) and the value factor (High Minus Low, HML). Fama and French (1995, 1996, 2008, 2012) persistently verified the three-factor model through empirical studies, and their research revealed that numerous anomalies can be elucidated by the three-factor model. The success of Fama and French's three-factor model has significantly contributed to the advancement and discussion of multifactor models in finance research. Carhart (1997) expanded upon the Fama and French (1993) three-factor model by incorporating the momentum effect, thereby developing a four-factor model. The findings indicated that this four-factor model provides a greater explanatory power for fund performance compared to the original three-factor model. Chen et al. (2010) utilized the return on assets (ROA) as a metric for assessing a company's profitability. Their findings suggest that companies with higher profitability levels tend to yield higher stock returns. Aharoni, Grundy, and Zeng (2013) identified a negative relationship between a company's investment activities and its stock returns. Hou, Xue, and Zhang (2015) considered both the return on equity (ROE) and the total assets growth rate as indicators of a company's profitability and investment capabilities, concluding that these factors significantly influence stock returns.

Building on their previous model, Fama and French (2015) introduced two additional factors: the profitability factor (Robust Minus Weak, RMW) and the investment factor (Conservative Minus Aggressive, CMA), thus creating a five-factor model. Their research demonstrated that this five-factor model surpasses the three-factor model in explanatory power. In a further development, Fama and French (2018) incorporated the momentum factor (Up Minus Down, UMD) to devise a six-factor model. The findings from the study indicate that the six-factor model outperforms other models in terms of explanatory power. In general, the Fama-French six-factor model has been found to be useful in explaining stock returns in a variety of world markets. However, there have been some studies that have found mixed results. For example, some studies have found that the model works well in developed markets, but not as well in emerging markets (Fama & French, 2017).

This study primarily draws upon the six-factor model proposed by Fama and French (2018), employing it to craft the necessary research methodologies and empirical models. This study spans from January 2010 to December 2021, focusing on an empirical examination and analysis of the Taiwan region stock market. It aims to assess the influence of several factors, including the market risk factor, the size factor, the value factor, the profitability factor, the investment factor, and the momentum factor, on the returns of stocks in the Taiwan region stock market. The principal aim of this investigation is to evaluate the six-factor model's capacity to explain stock returns in the Taiwan region stock market. Additionally, since the empirical results of the six-factor model among the emerging markets did not demonstrate exactly the same as the developed markets, it is interesting to analyze whether there are nonlinear phenomena between the six factors and stock returns. This study tends to delve into the nonlinear behaviors of factors such as the market risk factor, the size factor, the value factor, the profitability factor, the investment factor, and the momentum factor in the Taiwan region stock market.

2. Data and Methodology

The 2008 financial crisis inflicted significant damage on the global economy and stock markets. However, post-2010 witnessed a gradual recovery of the global economy and stabilization of stock markets. Consequently, this study delineates its research timeframe from January 2010 to December 2021, focusing on the Taiwan region stock market. Data for analysis were sourced from the Taiwan Economic Journal Database (TEJ), employing the Fama and French (2018) six-factor model to formulate the requisite methodologies and empirical models for conducting an empirical investigation on the Taiwan region stock market. This section describes the sources of data, the period of study, the variable definitions and methodological procedure.

2.1. Sources of Data

The designated period for this study spans from January 2010 to December 2021, a total of 144 months. The collection of sample data extends from January 2009 to December 2021. The discrepancy lies in the methodology for calculating the momentum factor, which, following Fama and French (2018), involves averaging stock returns from the $(t-13)$ to the $(t-2)$ month for the momentum factor. Furthermore, due to the minimal trading volumes of depositary receipts (DR) and the opaque financial disclosures of foreign companies relisting in Taiwan region (KY, The Kayman Islands), these entities were excluded from the study. As indicated in **Table 3**, the count of stock samples has progressively increased from 1195 to 1630. This study amassed a total of 201,454 observations.

2.2. The FF Six-Factor Model and Operational Definitions

The conceptualization of factors in this study is primarily grounded in the frameworks of the Fama and French (2015) five-factor model and the Fama and French (2018) six-factor model. This approach is complemented by a meticulous

Table 3. Statistics on number of sample stocks across years.

Year	No. of listed stocks	No. of sample stocks
2010	1322	1195
2011	1397	1249
2012	1447	1292
2013	1496	1335
2014	1539	1369
2015	1586	1416
2016	1624	1459
2017	1651	1489
2018	1694	1546
2019	1717	1578
2020	1730	1604
2021	1744	1630

Source: Taiwan region economic daily news database.

collection of pertinent sample data, with an emphasis on adapting these definitions to more accurately mirror the dynamics of the Taiwan region stock market. The specifics are delineated below,

$$R_{it} - R_{ft} = a_i + b_i Mkt_t + s_i SMB_t + h_i HML_t + r_i RMW_t + c_i CMA_t + m_i UMD_t + e_{i\,t} \quad (1)$$

where,

R_{it}: the expected return of security i in period t;

R_{ft}: the market risk-free rate in period t;

Mkt_t: Market Risk Factor ($R_{Mt} - R_{ft}$) in period t;

R_{Mt}: expected return of market portfolio M in period t;

SMB_t: Size Factor in period t, i.e., return of a small market capitalization portfolio minus return of a large market capitalization portfolio;

HML_t: Value Factor in period t, i.e., return of portfolio with high book-to-market ratio minus return of portfolio with low book-to-market ratio;

RMW_t: Profitability Factor for period t, i.e., return of a portfolio with strong profitability minus return of a portfolio with weak profitability;

CMA_t: Investment Factor for period t, i.e., return of conservative portfolio minus return of aggressive portfolio;

UMD_t: Momentum Factor for period t, i.e., return of dynamic portfolio minus return of weak portfolio;

a_i: intercept term;

b_i, s_i, h_i, r_i, c_i, and m_i: coefficients of the respective variables;

e_{it}: residual.

1) Market Risk Factor (Mkt)

The Market Risk Factor (Mkt) denotes the influence exerted on stock returns by fluctuations in the aggregate market. The computation of the market risk factor is delineated by the equation ($R_{Mt} - R_{ft}$), wherein R_{Mt} represents the anticipated return rate of the market investment portfolio M for the t^{th} period, and R_{ft} signifies the risk-free interest rate for the same period (divided by twelve). For the purposes of this analysis, the one-year time deposit rate offered by the Taiwan region Post Office is employed as the benchmark for the market's risk-free rate.

2) Size Factor (SMB)

The Size Factor (SMB) encapsulates the effect of a firm's market capitalization on its stock returns. To calculate the size factor, the initial step involves arranging the monthly data in ascending order based on market capitalization. The smallest 25% of companies form the small-size portfolio, while the largest 25% constitute the large-size portfolio. The returns for both the small-size and the large-size portfolios are computed independently. The size factor is subsequently derived by deducting the return rate of the large-size portfolio from that of the small-size portfolio.

3) Value Factor (HML)

The Value Factor (HML) delineates the influence exerted by a company's book-to-market ratio on its stock returns. To compute the value factor, monthly data are initially ranked according to the book-to-market ratio (inverse of the price-to-book ratio) in descending order. The portfolios comprising the highest 25% are deemed high book-to-market ratio portfolios, whereas the lowest 25% from the low book-to-market ratio portfolios. The returns for both portfolios are independently calculated, and the value factor emerges from the difference in returns between the high and low book-to-market ratio portfolios.

4) Profitability Factor (RMW)

The Profitability Factor (RMW) captures the effect of a company's profitability on its stock returns. This analysis employs the ratio of Operating Income to Owners' Equity as a measure of profitability. The sorting of quarterly sample data by this profitability measure, from highest to lowest, segregates the top 25% into a high profitability portfolio and the bottom 25% into a low profitability portfolio. After calculating the returns for both portfolios, the profitability factor is derived by subtracting the returns of the low profitability portfolio from the high profitability portfolio.

5) Investment Factor (CMA)

The Investment Factor (CMA) elucidates the impact of a company's investment strategy on stock returns, with the total assets growth rate serving as a proxy for the investment pattern. The investment factor calculation commences with the quarterly sample data being arranged by total assets growth rate in ascending order. The portfolios in the lowest 25% are categorized as conservative investment portfolios, while those in the highest 25% are deemed aggressive investment portfolios. After computing the returns for both sets of portfolios, the investment factor is determined by the difference in returns between the conservative and aggressive investment portfolios.

6) Momentum Factor (UMD)

The Momentum Factor (UMD) delineates the influence exerted by historical stock returns on present stock returns. To compute the momentum factor, an initial step involves determining the average return rate for the sample data from period ($t-12$) to ($t-2$), followed by ranking these average return rates in descending order. The portfolios in the highest 25% are deemed to have strong momentum, whereas those in the lowest 25% are considered to have weak momentum. The returns for both the strong and weak momentum portfolios are independently assessed. The momentum factor emerges from the differential in returns between the strong and weak momentum portfolios.

2.3. The Specifications of the Empirical Models

The primary aim of this investigation is to assess the six-factor model's capacity to elucidate stock returns in the Taiwan region stock market and to examine the nonlinear behaviors of factors such as the market risk factor, the size factor, the value factor, the profitability factor, the investment factor, and the momentum factor in the Taiwan region stock market. To fulfill the research goals, this study draws inspiration from the Fama and French (2018) six-factor model to craft the necessary empirical model. This encompasses a variety of models including traditional linear regression, quadratic models, and Panel Data regression models. The requisite empirical data are meticulously gathered to facilitate thorough computation, verification, and analysis.

2.3.1. The Traditional Linear Regression Model

In order to assess the six-factor model's capacity to elucidate stock returns in the Taiwan region stock market, this study draws upon the Fama and French (2018) six-factor model as a basis for constructing the necessary traditional linear regression model. The model is outlined as follows,

$$R_{it} - R_{ft} = \beta_0 + \sum_{j=1}^{6} \beta_{jt} X_{jt} + \varepsilon_{it} \tag{2}$$

where,

R_{it}: the expected return of security *i* in period *t;*

R_{ft}: the market risk-free rate in period *t;*

X_{jt}: $X_{1t} = Mkt_t$, $X_{2t} = SMB_t$, $X_{3t} = HML_t$, $X_{4t} = RMW_t$, $X_{5t} = CMA_t$, $X_{6t} = UMD_t$;

β_0: intercept term;

β_{jt}: coefficient of the respective variables;

ε_{it}: residual.

2.3.2. The Quadratic Model

In an effort to investigate the nonlinear behaviors of factors such as the market risk factor, the size factor, the value factor, the profitability factor, the investment factor, and the momentum factor in the Taiwan region stock market, this study draws inspiration from the stochastic beta model proposed by Chen and Stockum (1986) to formulate the necessary quadratic model. It posits that the β_{jt} for each factor is subject to variation over time and in relation to the magnitude of the factor itself. For instance, considering the market risk factor.

Let

$$\beta_{1t} = \delta_0 + \delta_{1t} Mkt_t \,, \tag{3}$$

By integrating Equations (3) into (2), the following equation is derived:

$$\begin{aligned} R_{it} - R_{ft} &= \beta_0 + \left(\delta_0 + \delta_{1t} Mkt_t\right) Mkt_t + \varepsilon_{it} \\ &= \beta_0 + \delta_0 Mkt_t + \delta_{1t} Mkt_t^2 + \varepsilon_{it} \end{aligned} \tag{4}$$

If $\delta_{1t} > 0$, then β_{1t} will rise when $Mkt_t > 0$. If $\delta_{1t} < 0$, then β_{1t} will fall when $Mkt_t > 0$, i.e., there is a Nonlinear phenomenon of the market risk factor. If $\delta_{1t} = 0$, then β_{1t} is a constant, i.e., Nonlinearity does not exist in the market risk factor. The interpretation of other factors is similar to that of the first factors, which could be expressed as follows.

$$R_{it} - R_{ft} = \beta_0 + \sum_{j=1}^{6} \beta_{jt} X_{jt} + \sum_{j=1}^{6} \delta_{jt} X_{jt}^2 + \varepsilon_{it} \tag{5}$$

where,

R_{it}: the expected rate of return of security *i* in period *t*.

R_{ft}: the market risk-free rate in period *t*.

X_{jt}: $X_{1t} = Mkt_t$, $X_{2t} = SMB_t$, $X_{3t} = HML_t$, $X_{4t} = RMW_t$, $X_{5t} = CMA_t$, $X_{6t} = UMD_t$.

β_0: intercept term.

β_{jt} and δ_{jt}: coefficients of the respective variables.

ε_{it}: residual.

2.3.3. The Panel Data Regression Model

Beyond the empirical models previously discussed, this study acknowledges the dual nature of the sample, which exhibits both cross-sectional and time-series attributes. Consequently, this study adopts the panel data regression model's framework and methodology. This approach aims to mitigate biases encountered during the estimation process, thereby striving to elevate the precision of the analytical outcomes. The standard formulation of the panel data regression model is presented below,

$$Y_{it} = \beta_0 + \beta' X_{it} + \varepsilon_{it} \tag{6}$$

Let $\varepsilon_{it} = \mu_i + \nu_{it}$, $i = 1, \ldots, N$; $t = 1, \ldots, T$. N is the number of the firms, and T is the length of time series period.

Where,

Y_{it}: vector of dependent variables.

X_{it}: vector of independent variables.

β_0: intercept term.

β: vector of regression parameters.

ε_{it}: residual term.

μ_i: Individual-related, no change over time.

ν_{it}: residual term that changes with time.

The panel data regression models are categorized into fixed effect models and random effect models, with their primary distinction rooted in their respective assumptions regarding the intercept term. According to Mundlak (1978), if the intercept term in a random model exhibits correlation with the independent variables, it introduces bias, necessitating the use of a fixed effect model. Conversely, if there is no correlation between the intercept term and the independent variables in a random model, a random effect model is appropriate. The selection between these models can be facilitated by employing the Hausman (1978) test, which aids in deciding whether a fixed effect model or a random effect model is more suitable.

3. Empirical Results and Analysis

This study is primarily based on the Fama and French (2018) six-factor model, from which it derives the necessary traditional linear regression model, quadratic model, and panel data regression model. The timeframe for this study spans from January 2010 to December 2021, focusing on an empirical examination and analysis of the Taiwan region stock market. The core objective of this study is to assess the six-factor model's ability to explain stock returns in the Taiwan region stock market and to investigate the nonlinear behaviors exhibited by factors such as the market risk factor, the size factor, the value factor, the profitability factor, the investment factor, and the momentum factor in the Taiwan region stock market.

3.1. Descriptive Statistics and Correlation Analysis

Referencing in Table 4, within the timeframe of Jan. 2010 to Dec. 2021, the market risk factor averages at 0.6030%, suggesting that the market investment portfolio's returns surpass those of the risk-free market rate. The size factor's average stands at −1.2174%, indicating the small market capitalization portfolio's returns do not exceed those of the large market capitalization portfolio. The value factor's average is recorded at −3.2685%, showing that the high book-to-market ratio portfolio's returns do not surpass those of the low book-to-market ratio portfolio. The profitability factor averages 0.0345%, denoting that the high profitability portfolio's returns are superior to those of the low profitability portfolio. The investment factor's average is 0.1007%, signifying that the conservative investment portfolio's returns outperform those of the aggressive investment portfolio. The momentum factor averages at 2.3284%, illustrating that the strong momentum portfolio's returns are superior to those of the weak momentum portfolio. In terms of factor variability, the market risk factor exhibits the highest standard deviation at 11.9140%, while the profitability factor shows the lowest standard deviation at 0.8666%.

As depicted in Table 5, the excess stock returns ($R_{it} - R_{ft}$) are positively correlated with all six factors. The market risk factor, aside from a negative correlation with the size factor (−0.0554), shows positive correlations with the value factor (0.1479), the profitability factor (0.1539), the investment factor (0.0946), and the momentum factor (0.1055). Conversely, the size factor displays negative correlations with the market risk factor (−0.0554), the profitability factor (−0.2222), and the momentum factor (−0.0878), but positive correlations with the value factor (0.2706) and the investment factor (0.1749).

The value factor exhibits negative correlations with both the profitability factor (−0.0175) and the momentum factor (−0.1352), while it shows positive correlations with the market risk factor (0.1479), the size factor (0.2706), and the investment factor (0.2386). Conversely, the profitability factor demonstrates negative correlations with the size factor (−0.2222), the value factor (−0.0175), and the investment factor (−0.2623), but it is positively correlated with the market risk factor (0.1539) and the momentum factor (0.1229).

Table 4. Descriptive statistics of the sample.

Variable	Sample Size	Mean	Std. Dev.	Min	Max
$R_{it} - R_{ft}$	201,454	1.0049	11.9140	−70.9313	249.0007
Mkt	201,454	0.6030	4.0225	−14.0934	13.1619
SMB	201,454	−1.2174	2.5674	−7.4834	5.9124
HML	201,454	−3.2685	2.4007	−9.9633	3.0589
RMW	201,454	0.0345	0.8666	−2.4415	2.6920
CMA	201,454	0.1007	0.9250	−1.9849	2.6193
UMD	201,454	2.3284	1.8962	−0.9424	11.2716

Table 5. Pearson correlation tests (N = 201,454).

	$R_{it} - R_{ft}$	Mkt	SMB	HML	RMW	CMA
Mkt	0.3577***					
	(<0.0001)					
SMB	0.0731***	−0.0554***				
	(<0.0001)	(<0.0001)				
HML	0.0473***	0.1479***	0.2706***			
	(<0.0001)	(<0.0001)	(<0.0001)			
RMW	0.0272***	0.1539***	−0.2222***	−0.0175***		
	(<0.0001)	(<0.0001)	(<0.0001)	(<0.0001)		
CMA	0.0546***	0.0946***	0.1749***	0.2386***	−0.2623***	
	(<0.0001)	(<0.0001)	(<0.0001)	(<0.0001)	(<0.0001)	
UMD	0.0629***	0.1055***	−0.0878***	−0.1352***	0.1229***	−0.0280***
	(<0.0001)	(<0.0001)	(<0.0001)	(<0.0001)	(<0.0001)	(<0.0001)

Note: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$; p value in parenthesis.

Furthermore, the investment factor reveals negative correlations with the profitability factor (−0.2623) and the momentum factor (−0.0280), yet it is positively correlated with the market risk factor (0.0946), the size factor (0.1749), and the value factor (0.2386). The momentum factor, on the other hand, shows negative correlations with the size factor (−0.0878), the value factor (−0.1352), and the investment factor (−0.0280), while maintaining positive correlations with the market risk factor (0.1055) and the profitability factor (0.1229).

3.2. Validation of the Six-Factor Model in Taiwan Region

Drawing upon the Fama and French (2018) six-factor model, this study crafts the necessary empirical model to rigorously validate the model's capacity to elucidate stock returns in the Taiwan region stock market through detailed calculations, tests, and analyses.

As depicted in **Table 6**, Model I show that the adj. R^2 stands at 0.1387, and the F statistic reaches 5407.2 ($p < 0.0001$), with significant t-test outcomes for the market risk factor, the size factor, the value factor, the profitability factor, the investment factor, and the momentum factor. These findings indicate the six-factor model has significant explanatory power regarding stock returns in the Taiwan region stock market. Significant positive impacts on stock returns are observed for the market risk factor (1.0823), the size factor (0.4699), the investment factor (0.1113), and the momentum factor (0.1895); whereas the value factor (−0.1602) and the profitability factor (−0.1179) exhibit significant negative impacts on stock returns. The VIF (Variance Inflation Factor) indexes are far less than 10, indicating there is no significant collinearity problem. Besides, Model II demonstrate that the quadratic terms are highly significant in five factors, except for

Table 6. Results of traditional linear and quadratic reg. models.

	Model I: Traditional linear regression model			Model II: The Quadratic model	
	Coef.	t	VIF	Coef.	t
Intercept	−0.0476	−0.94	-	0.1204	1.84*
Mkt	1.0823	170.11***	1.0792	1.0789	165.23***
Mkt^2				−0.0081	−9.46***
SMB	0.4699	45.7***	1.1483	0.4746	43.20***
SMB^2				0.0044	1.55
HML	−0.1602	−14.37***	1.1811	−0.2429	−8.54***
HML^2				−0.0099	−2.71***
RMW	−0.1179	−3.84***	1.1656	−0.1931	−5.94***
RMW^2				−0.0617	−2.87***
CMA	0.1113	3.88***	1.1613	0.0330	1.08
CMA^2				0.0962	3.95***
UMD	0.1895	14.24***	1.0481	−0.0383	−1.17
UMD^2				0.0372	8.66***
F-value		5407.2***		2724.2***	
p-value		<0.0001		<0.0001	
R^2		0.1387		0.1396	
Adj. R^2		0.1387		0.1396	
Sample Size		201,454		201,454	

Note: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

SMB (the size factor). These results imply the overconfidence nature of emerging markets and require further investigation.

Beyond the traditional linear and quadratic regression models, this study acknowledges the dual nature of the sample data, incorporating both cross-sectional and time-series elements. Consequently, it leverages the panel data regression model's framework and methodology to capture a more comprehensive view, aiming to mitigate estimation biases and enhance analytical precision. As indicated in Table 7, the study employs the random effects Hausman test and concludes that the alternate hypothesis of random effects is rejected. The fixed-effects model would be applied to the linear and quadratic models.

As detailed in Table 8, the results of linear and quadratic panel data regression models are reported. In Model III, the adj. R^2 stands at 0.1454, with an F statistic of 2.9967 ($p < 0.0001$). The t-tests for the market risk factor, the size factor, the value factor, the profitability factor, the investment factor, and the momentum factor all yield significant results. These findings indicate that the six-factor model effectively explains stock returns in the Taiwan region stock market, with the Panel Data regression model demonstrating superior explanatory power compared to the traditional linear regression model. Significant positive impacts on stock returns are observed for the market risk factor (1.0672), the size factor (0.4752), the investment factor (0.1338), and the momentum factor (0.2409). Conversely, the value factor (−0.1776) and the profitability factor (−0.0876) exhibit significant negative impacts on stock returns.

Table 7. Hausman test of random effects.

Coefficient	DF	m-value	*p*-value
6	6	89.04***	<0.0001

Note: **p* < 0.1, ***p* < 0.05, ****p* < 0.01.

Table 8. Results of panel data linear and quadratic models.

Variables	Model III: Linear Regression Model		Model IV: Quadratic Model	
	Coef.	t-value	Coef.	t-value
Intercept	3.8365	1.21	3.8154	1.20
Mkt	1.0672	160.42***	1.0645	155.29***
Mkt^2			−0.0088	−9.12***
SMB	0.4752	45.11***	0.4770	41.68***
SMB^2			0.0050	1.70*
HML	−0.1776	−15.14***	−0.2433	−8.29***
HML^2			−0.0085	−2.27**
RMW	−0.0876	−2.76***	−0.1551	−4.56***
RMW^2			−0.0709	−3.23***
CMA	0.1338	4.49***	0.0551	1.71*
CMA^2			0.0950	3.73***
UMD	0.2409	16.06***	0.0500	1.44
UMD^2			0.0311	6.86***
F-value	2.9967***		3.0078***	
p-value	<0.0001		<0.0001	
R^2	0.2182		0.2189	
Adj. R^2	0.1454		0.1461	
Sample Size	201,454		201,454	

Note: **p* < 0.1, ***p* < 0.05, ****p* < 0.01.

In Model IV, the adj. R^2 stands at 0.1461, with an F statistic of 2724.2 ($p <$ 0.0001). With the exception of the momentum factor's insignificant t-test outcome, significant results were observed for the market risk factor (1.0645), the squared market risk factor (−0.0088), the size factor (0.4770), the squared size factor (0.0050), the value factor (−0.2433), the squared value factor (−0.0085), the profitability factor (−0.1551), the squared profitability factor (−0.0709), the investment factor (0.0551), and the squared investment factor (0.0950). These findings indicate the presence of nonlinear behaviors among the market risk factor, the size factor, the value factor, the profitability factor, and the investment factor in the Taiwan region stock market, as illustrated in Figure 3.

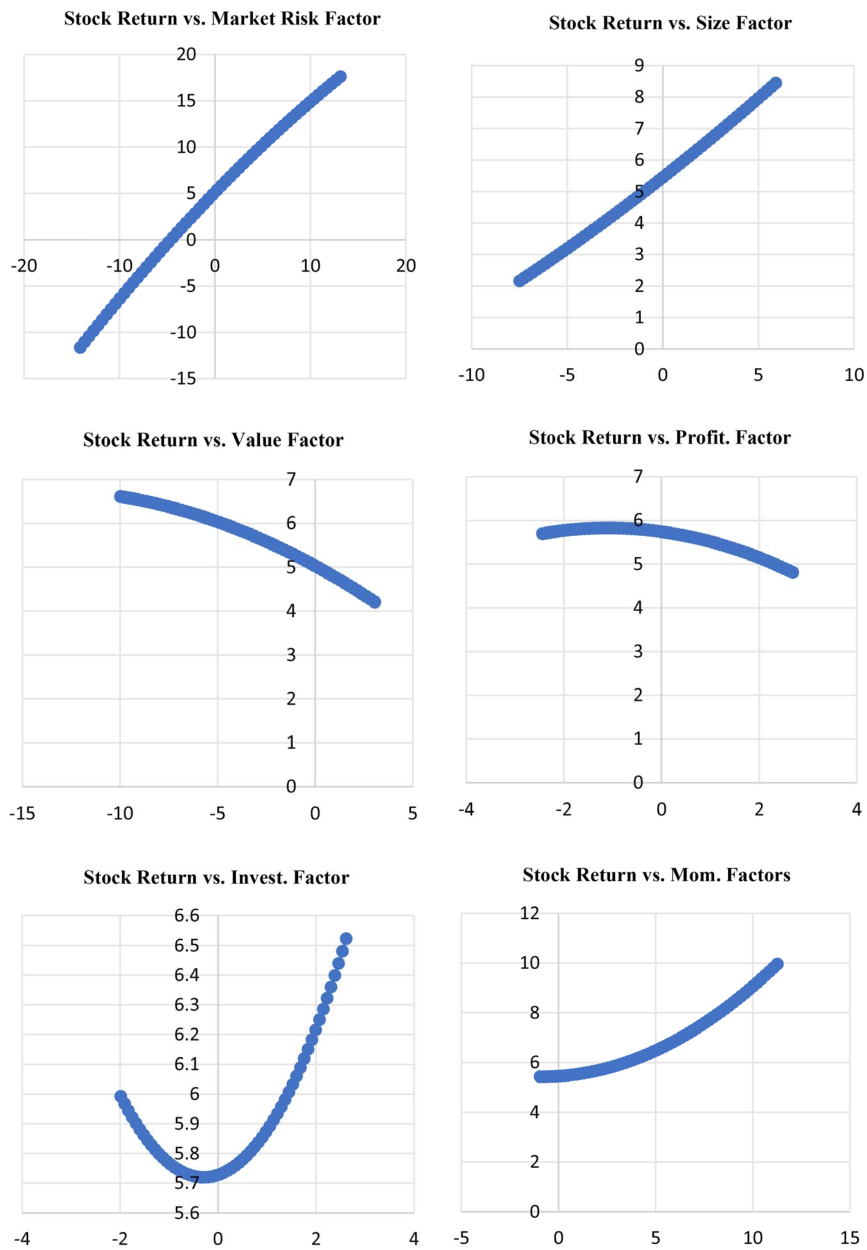

Figure 3. The nonlinear relationship between the six factors and excess stock returns.

3.3. Comparative Analysis of International Stock Markets

Fama and French (2017) broadened the scope of their three-factor and five-factor models to encompass international stock markets, conducting validations across North America (USA, Canada), Japan, the Asia-Pacific region (Australia, New Zealand, Hong Kong (China), Singapore), and Europe (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and UK).

In a subsequent development, Fama and French (2018) integrated the momentum factor into the five-factor framework, thereby establishing the Fama and French (2018) six-factor model. Grobys and Kolari (2022) pursued this line of inquiry further, applying the Fama and French (2018) six-factor model in their international stock markets validations, following the precedent set by Fama and French (2017).

Huang (2019) focused on the Chinese stock market, evaluating a range of models including the capital asset pricing model, the Fama and French (1993) three-factor model, the Carhart (1997) four-factor model, the Fama and French (2015) five-factor model, and the six-factor model that emerges from augmenting the Fama and French (2015) five-factor model with the momentum factor.

This study focuses on the application of the six-factor model in the Taiwan region stock market. The study reveals that the efficacy of individual factors in the six-factor model varies across different international stock markets. As detailed in **Table 9**, the market risk factor, the size factor, the value factor, the profitability factor, the investment factor, and the momentum factor contribute positively to stock returns in the stock markets of North America, Japan, and Europe. On the other hand, in the Chinese stock market, only the market risk factor and the size factor positively affect stock returns, whereas the value factor, the profitability factor, the investment factor, and the momentum factor negatively affect stock returns. Whereas the stock market under Taiwan region emerging environment, the market risk factor, the size factor, the investment factor, and the momentum factor positively influence on stock returns, while the value factor and the profitability factor exert a negative influence on stock returns.

Table 9. Comparison of the six factors effects among selected international stock markets.

Factors	North America	Japan	Asia Pacific	Europe	China
Mkt	Positive	Positive	Positive	Positive	Positive
SMB	Positive	Positive	Negative	Positive	Positive
HML	Positive	Positive	Positive	Positive	Negative
RMW	Positive	Positive	Positive	Positive	Negative
CMA	Positive	Positive	Positive	Positive	Negative
UMD	Positive	Positive	Positive	Positive	Negative

4. Conclusion

This study is grounded in the six-factor model, from which it derives the methodologies and empirical models necessary for conducting an in-depth analysis of the Taiwan region stock market over the period from Jan. 2010 to Dec. 2021. The objective was to assess the six-factor model's capacity to explain stock returns in the Taiwan region stock market. Findings from the study indicate that, based on analyses conducted using both traditional linear regression and panel data regression models, the six-factor model effectively elucidates stock returns in the Taiwan region stock market.

Beyond merely validating the six-factor model's applicability to the Taiwan region stock market, this investigation also delves into the nonlinear dynamics exhibited by factors such as the market risk factor, the size factor, the value factor, the profitability factor, the investment factor, and the momentum factor in the Taiwan region stock market. Results reveal the presence of nonlinear phenomena associated with the market risk factor, the value factor, and the profitability factor when analyzed through traditional linear regression models. Similarly, nonlinear phenomena related to the market risk factor, the size factor, the value factor, the profitability factor, and the investment factor were identified in the panel data regression model framework, underscoring the complex interplay of these factors in the Taiwan region stock market.

This study additionally reveals that the efficacy of individual factors in the six-factor model could vary across developed and developing stock markets environments. These variances might be attributable to differences in financial regulatory constraints, cultural contexts, overconfident behaviors, economic development levels, or the openness of stock markets. The findings offer avenues for further investigation and research directions for scholars in the field.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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