Revue Internationale du Chercheur
ISSN: 2726-5889
Volume 6 : Numéro : 3

Comparative study of the performance of the Fama & French 3-factor model: the case of the Moroccan equity market

Etude comparative de la performance du modèle à 3 facteurs de Fama & French : le cas du marché des actions marocain

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Date de soumission : 17/06/2025
Date d'acceptation : 03/08/2025
Pour citer cet article :
ELHASNAOUI.T & Al (2025) «Comparative study of the performance of the Fama & French 3-factor model: the case of the Moroccan equity market», Revue Internationale du chercheur «Volume 6 : Numéro 2 » pp :85 - 106

Résumé :

L'objectif de ce document est d'analyser la performance du modèle à trois facteurs de Fama et French sur deux périodes différentes. La première période a été marquée par une crise pandémique sans précédent qui a provoqué la volatilité des principaux marchés mondiaux, tandis que la seconde a été marquée par une période de stabilité économique. L'échantillon contient 20 titres de différents secteurs considérés comme les plus liquides sur le marché boursier et qui composent l'indice MSI 20. Les résultats montrent qu'il est difficile d'utiliser les modèles d'évaluation des actifs inspirés de la théorie du portefeuille pour estimer les rendements boursiers en période de crise financière. Contrairement à cette première réalité, les modèles de la théorie du portefeuille sont parfaits en période de faible et moyenne volatilité, et reflètent la réalité en période de stagnation des marchés financiers. Les estimations univariées montrent la supériorité des facteurs taille et valeur sur la prime de risque de marché (PRM) en période de forte volatilité, et l'amélioration de la qualité prédictive de la PRM lorsqu'elle est combinée aux effets taille et valeur dans les deux périodes. Les estimations multi-variées révèlent la capacité du modèle à prédire les rendements boursiers en période de volatilité faible ou moyenne.

Mots clés : Fama & French, SMB, HML, PRM, COVID-19, volatilité

Abstract

The purpose of this paper is to analyze the performance of the Fama and French 3-factor model over two different periods. One period saw an unprecedented pandemic crisis causing volatility in the world's main and another period of economic stability. The sample contains 20 stocks from different sectors considered to be the most liquid on the stock market and which make up the MSI 20 index. The results show that it is difficult to use asset pricing models theoretically inspired by portfolio theory to estimate stock market returns in times of financial crisis. Contrary to this first reality, portfolio theory models are perfect during periods of low and medium volatility, and reflect reality during periods of financial market stagnation. The univariate estimates show the superiority of the size and value factors over the market risk premium (MRP) in periods of high volatility, and the improved predictive quality of the MRP when combined with the size and value effects in both periods. Multi-variate estimates reveal the model's ability to predict stock market returns in periods of low or medium volatility.

Keywords: Fama & French, SMB, HML, PRM, COVID-19, volatility

Introduction

One of the most studied and tested financial variables is the stock market price (return), and the ultimate goal of academics and portfolio management practitioners is to predict and forecast this variable. To do this, they strive to determine the variables that play a role in explaining stock market returns. One such variable is MRP, which features in the Capital asset pricing model (CAPM) introduced by portfolio theory following SLB[1]'s work.

Finance has been turned upside down by the emergence of this model, which considers that the return on an asset or portfolio is completely explained by a single factor: MRP. According to the rationality hypothesis, the price of a financial asset at any given moment reflects its true value, known as its fundamental value, or intrinsic value. The efficiency hypothesis stipulates that the price immediately incorporates all available information, so that no one can beat the market.

According to Fama, the price posted on the market and which has incorporated all available information is a good estimator of the intrinsic value of this security. In fact, these two closely related hypotheses have been beaten by the emergence of a series of phenomena observed on financial markets and referred to as anomalies, which refute the efficiency hypothesis.

To avoid questioning efficiency and the CAPM being a model strongly based on this assumption, Fama & French introduced two factors linked to size and value. By adding these two factors to the CAPM, the model would provide more explanations for the profitability of financial assets.

In 1993 Fama, in collaboration with French, published an article in which they announced their model as valid and more significant on the american market, and advocated its use. In the context of this model, a great deal of research has been carried out to test its robustness. In fact, the model has been validated on both developed and emerging markets, and its predictive and explanatory power has improved in comparison with the uni-factor model. It should be noted that the number of empirical financial applications of this model in Morocco is small, which is why this paper attempt to contribute our knowledge to improve it and to introduce Moroccan researchers to the use of multi-factor models to perfect the prediction of stock market returns.

The aim of this paper is to study the explanatory and predictive power of the model, as well as to evaluate the actions in two contexts: a context marked by the health crisis, where the market experienced a sharp decline linked to the negative economic effects of covid 19, and a non-

[1] Corresponds to Sharp (1964), Lintner (1965) and Black (1966) who introduced the CAPM independently.

crisis context, where the extent of volatility was less than that recorded during the health crisis, and to reveal the period when the model was perfected.

To address this issue, we adopt two methodological approaches. First, we undertake a univariate analysis, testing three distinct uni-factor models. Second, we carry out a multivariate analysis, evaluating Fama & French's 3-factor model.

Of course, the object leaves us to ask the following questions:

- Are the size effect and the value effect considered as factors with weight in the explanation and prediction of stock market returns?
- Does adding these two anomalies to the CAPM improve the model's significance?
- To what extent could the model combining the three factors mentioned above be a good estimator of stock returns?
- When does the model reflect market reality?

In consideration of the results, we will compare the three factors on the one hand and the two periods on the other. The paper is organized as follows:

In the first section, we will review the Fama & French three-factor model and present a brief review of the literature on the model. The second section deals with the procedure for constructing independent and dependent factors and describes the methodology adopted. The third section will be devoted to the results of the various estimates.

Literature review

Inspired by the work of Bassu (1977), who proposed the inclusion of the BTM factor “BV/MV” in Sharp's model as a powerful and preferred factor for predicting stock market returns, and the work of Banz (1981), who suggested including the factor “company size” in Sharp's model as an important factor with a degree of explanation exceeding that of beta, the 2 authors put forward the idea of a model containing more than one factor in its structure.

In 1993, Fama & French tested their model on the AMEX, NASDAQ and NYSE for a period stretching from 1963 to 1990. After applying their methodology, widely presented and cited in academic studies, they arrived at the truth of the absence of a linear relationship between return and beta. This prompted them to utter their famous phrase “the death of beta”. Moreover, the relationship between returns and the other 2 factors was strong and significant, and even more so between returns and the BV/MV ratio. This demonstrates the importance of these two company-specific factors in explaining stock market performance. What is revealing in their test is the breakdown of the two factors into different classes. Indeed, companies with a high

BV/MV ratio and small size are the ones that generate attractive returns compared to the other classes. According to Fama & French's research, stock market returns cannot be explained by a single factor common to all stocks: it's the market as a whole. On the other hand, company-specific aspects may play a major role in explaining stock market returns.

Fama & French's three-factor model has been extensively tested since its inception, and has revolutionized the way stock market returns are explained. The aim of these tests was to gauge the model's ability to predict stock market returns. We will explore a collection of previous articles that have addressed the question of its validity and its ability to better reflect market reality.

In 2011 and on the Amman Stock Exchange, Karasneh and Al Mwalla tested the degree of prediction of the three-factor model over a period from 1999 to 2010. They found that the model is valid and that the size effect and the value effect stand out.

In order to determine which of the explanatory variables included in the 3-factor model has the most explanatory power, Sijilmassi tested the validity of Fama & French's 3-factor model using data provided by the Marogest management company. The sample includes all stocks listed on the Casablanca stock exchange for the period from January 2008 to December 2018. In terms of methodology, the author has ranked the market capitalization of all stocks in order to get an idea of how companies rank by size, and calculated the BV/MV ratio for all stocks. This classification and calculation enabled him to create 6 portfolios of different classes. The results showed that size, as measured by the SMB derivative portfolio, has the greatest influence on stock profitability, followed by the BV/MV factor and, lastly, PRM.

In 2016, Kianpoor and Dehghani refuted the 3-factor model, after conducting a study of Iran's financial market from 2008 to 2012, with the aim of estimating theoretical stock returns and comparing them with actual returns. To select stocks and estimate their returns, the authors adopted a methodology similar to that proposed by Fama & French.

Using Moroccan and Tunisian data, and with a view to determining the performance of financial assets, Mounira Ghniguir (2021) estimated the three-factor model. The conclusions drawn from his study led them to approve the model's validity and retain it as a reference model for securities portfolio management.

In 2019 and on the Qatar stock exchange, Yahia Fares was interested in explaining variations in stock market returns, for which he deployed the multifactor model for a period running from 10/01/2019 to 31/12/2019. A sample of 13 banks listed on the Qatar Stock Exchange was selected and regressed. The regression results show that MRP is significant and positive, and therefore explains a significant proportion of the variations in returns, unlike the other two factors (size and BTM ratio), which were found to explain only a small proportion of the variations in stock market returns. This suggests that, despite the model's performance and success on other financial markets, it has been applied to the Qatari financial market with little success, calling its use into question.

On the Pakistani financial market, Iqbal et Al (2017) tested the significance of the factors presented in the Fama & French 3-factor model. The period of their test spans 1984 to 2012, with the two authors applying panel least squares to regress the Pakistani equity excess returns series on the market excess returns series. At the end of the regression, both authors found that the relationship between the factors and stock market returns was linear. As for significance, all three factors are significant. Iqbal et al conclude that the model is valid.

The "Islamic" risk factor and its relationship to several macroeconomic variables, including inflation and the interest rate spread, are examined in the paper by BEN Mdalla (2022), which was published in the Revue Française d'Économie et de Gestion. The author demonstrates how this component responds strongly to macroeconomic shocks, which makes it a useful addition to conventional asset pricing models. These findings demonstrate how Fama and French's model may be improved by adding elements unique to the Islamic financial environment.

1. Methodology

This research proposes a comparative analysis of the explanatory capacity of Fama and French's three-factor model applied to the Moroccan equity market. The study focuses on a panel of twenty MASI 20 stocks for two key periods: the COVID-19 crisis phase (2020) and the post-pandemic phase (2022). The SMB, HML and PRM variables were developed according to the methodological approach defined by Fama and French (1993).

1.1 Sample and study data

The sample size comprises the twenty daily closing price series of Moroccan equities over a 252-day period, selected for their high trading volume, listing frequency and market capitalization on the Casablanca market.

Study data were collected over two periods. A first period running from 2/1/2020 to 31/12/2020 and a second period running from 2/1/2022 to 31/12/2022.

The choice of these two periods is equivalent to comparing a period that saw covid 19, which caused a spectacular fall in the world's main stock market indices, with another period that is just as mediocre, but whose volatility is no greater than that recorded in 2020.

Our idea is to test the ability of the Fama & French three-factor model to reflect market reality during the two periods mentioned above.

The recurring history of economic and financial crises reveals the inability of financial asset valuation models to accurately reflect stock market returns, particularly during periods of high volatility. This is why we have turned our attention to the Fama & French model, one of the most sophisticated models available, to compare its results over two periods. A period of high volatility and another of declining volatility.

We used the website of the Casablanca Stock Exchange to obtain the market value of each company, and we consulted the official websites of the companies to obtain the data included in the financial statements for calculating the BV (book value) and reporting it by the MV (Market value), in order to calculate the BTM ratio.

1.2 The procedure for constructing dependent and independent factors

A two-stage procedure was followed to build the three-factor model. The first stage is based on the construction of the different portfolios being the dependent factors, and the second stage is mainly based on the construction of the independent factors.

The methodology for constructing the dependent and independent factors is strikingly similar to that presented by Fama & French in their 1993 article. In fact, all the stocks in the sample are ranked by market capitalization in descending order and are divided into three size portfolios (small, medium and large), with the same number of stocks for the two portfolio categories (small and large) and eight stocks for the third category. In other words, one-third of small-cap stocks go into the small-cap portfolio, one-third of large-cap stocks go into the large-cap portfolio, and the remainder of mid-cap stocks go into the mid-cap portfolio.

They are then classified again, regardless of market capitalization, according to BTM ratio, and divided into two BTM ratio portfolios (low and high). We then proceeded to intersect two market capitalization groups and two BTM ratio groups, creating four portfolios (SH, BH, SL, BL).

- SL: Small-cap equity portfolio with low BTM ratio
- SH: Equity portfolio with small market capitalization and high BTM ratio.
- BL: Equity portfolio with large market capitalization and low BTM ratio.

- BH: A portfolio of equities with a large market capitalization and a high BTM ratio.

Before calculating the independent factors, we recall the model, which is written as follows:

$$R_p - R_f = \alpha + \beta\left(R_m - R_f\right) + s_i SMB + h_i HML + e_i$$

With:

R_p-R_f: is the excess return on the portfolio

R_m-R_f : represents the Market Risk Premium

SMB: The company size factor, measured by market capitalization, is determined as follows: ((SH+SL) -(BL+BH)) /3

HML: the BTM ratio measured by the BV/MVs ratio and obtained as follows: ((SH+BH) -(Bl+SL)) /2

β_i, s_i, h_i : represent separately the sensitivity coefficients of each factor in relation to the portfolio's excess return.

We remind that the formula for calculating stock returns is the logarithm of the price observed on day t divided by the previous day. This logarithmic method is considered the most widely accepted in professional and academic circles. Its formula is written as follows R = ln (p)/ln(p-1). Consequently, we have used the series of stock returns to calculate the series of portfolio returns, by calculating the average return on the stocks making up each portfolio.

Descriptive statistics tables

Table n°1 : Descriptive statistics 2020

	Bh-Rf	BL-Rf	SH-Rf	Sl-Rf	RM-Rf	SMB	HML
Mean	-0.000706	-0.000324	-0.000348	0.000408	-0.000105	0.000363	-0.000569
Median	0.000481	0.000106	0.000551	-7.87E-05	0.000440	0.000684	-0.000897
Maximum	0.070783	0.037691	0.041255	0.045507	0.051810	0.029213	0.025234
Minimum	-0.105013	-0.083502	-0.030648	-0.074785	-0.091642	-0.019990	-0.018749
Std.Dev	0.016364	0.012666	0.009336	0.012840	0.014066	0.006703	0.007322
Skewness	-1.525857	-1.447703	0.086663	-1.615759	-1.896831	0.138071	0.268855
Kurtosis	13.82050	11.92039	5.221321	12.23792	15.34842	4.486734	3.353164
JB	1311.361	912.5503	51.50471	993.7362	1731.332	23.72381	4.293755
Proba	0.000000	0.000000	0.000000	0.000000	0.000000	0.000007	0.116848

Source: Authors

From the descriptive statistics, we can see that all mean returns are negative except for the SL elementary portfolio and the SMB derivative portfolio. This was due to the turbulent financial market during the covid year. Returns vary between 0.07 and -0.10. The normality hypothesis is rejected, since all probabilities are below 5%, with the exception of the HML, whose probability is above 5% and whose JB statistic is below its critical value of the chi-square distribution at 5% risk (5.99). We observe that the yields have a leptocurtic distribution, since all the kurtosis are greater than 3, with the exception of the HML factor whose kurtosis is close to 3. The excess kurtosis indicates the presence of extreme values, contrary to what the normal distribution would predict.

All distributions are spread to the left due to the negativity of Skewness, with the exception of the elementary SH portfolio and the two derivative portfolios SMB and HML. This spread attests to the scale of the losses.

Table n°2: Descriptive statistics 2022

	Bh-Rf	BL-Rf	SH-Rf	Sl-Rf	RM-Rf	SMB	HML
Mean	0.000182	0.000383	0.000147	9.57E-05	0.000306	-0.000107	-7.49E-05
Median	-8.84E-05	-0.000150	0.000112	-3.99E-05	-5.72E-05	-9.19E-05	-7.63E-05
Maximum	0.024181	0.017950	0.026629	0.023638	0.020083	0.013319	0.010581
Minimum	-0.012764	-0.012328	-0.021488	-0.016051	-0.010754	-0.011802	-0.012165
Std.Dev	0.004386	0.004924	0.006508	0.005964	0.003699	0.003191	0.004311
Skewness	0.989297	0.486364	0.183236	0.421082	1.154806	0.043540	-0.108978
Kurtosis	7.789677	3.813920	4.890662	4.154534	7.685540	4.454871	3.309206
JB	283.1053	16.95800	39.09805	21.52808	287.6673	22.39296	1.508658
Proba	0.000000	0.000208	0.000000	0.000021	0.000000	0.000014	0.470326

Source: Authors

Like the average returns for 2020, the averages for 2022 are all positive, with the exception of the two derivative portfolios SMB and HML. This is to be expected, since the year 2022 has not been characterized by an event with a roughness similar to that of covid 19. As for yields, they vary between 0.026 and -0.02, which suggests that, in terms of volatility was lower than in 2020.

The violation of the normality assumption is confirmed, since all probabilities are below 5% except for the HML derivative portfolio, whose probability is above 5%. The leptokurtic distribution is only present for the elementary portfolio BH and MRP, and therefore the presence of extreme values is only present for these two products. Only the HML factor, whose distribution is spread to the left due to the negativity of its skewness, and therefore the scale of its losses exceeds its gains.

Table n°3 : Stationarity study 2020

Model	**Intercept**	**None**	**Trend & intercept**

BH-rf	t-stic = -14.94 P-value = 0	t-stic = -14.94 P-value = 0	t-stic = - 5.59 P-value = 0
BL-rf	t-stic = -13.26 P-value = 0	t-stic = -13.28 P-value = 0	t-stic = -13.35 P-value = 0
SL-rf	t-stic = -14.48 P-value = 0	t-stic = -14.50 P-value = 0	t-stic = -14.46 P-value = 0
SH-rf	t-stic = -14.63 P-value = 0	t-stic = -14.64 P-value = 0	t-stic = -14.69 P-value = 0
RM-rf	t-stic = -12.74 P-value = 0	t-stic = -12.76 P-value =0	t-stic = -12.83 P-value = 0
SMB	t-stic = -16.48 P-value = 0	t-stic = -16.46 P-value = 0	t-stic = -16.66 P-value = 0
HML	t-stic = -16.53 P-value = 0	t-stic = -16.46 P-value = 0	t-stic = -16.62 P-value = 0

Source : Authors

Checking stationarity is an essential step that must be taken before proceeding with estimations. After conducting an informal test based on visual examination of the graphical representation and exploration of the ACF, we will say that all series are stationary. This doesn't prevent us from deploying a test to confirm the result we've achieved visually.

The most commonly used test is the ADF test, based on a sequential strategy using 3 autoregressive models of order 1.

Table-3 above shows the results of the ADF[2] test. We can see that the t-stats are strictly below their critical values at the 5% threshold, and that the probabilities associated with these tests are all below 0.05. This argues in favor of the absence of a unit root in the structure of the time series. This argues in favor of the absence of a unit root in the structure of the time series.

Table n°4 : Stationarity study 2022

Model	Intercept	None	Trend & intercept
BH-rf	t-stic = -17.74 P-value = 0	t-stic = -17.75 P-value = 0	t-stic = -17.71 P-value = 0
BL-rf	t-stic = -15.57 P-value = 0	t-stic = -15.53 P-value = 0	t-stic = -15.54 P-value = 0
SL-rf	t-stic = -16.92 P-value = 0	t-stic = -16.94 P-value = 0	t-stic = -16.91 P-value = 0
SH-rf	t-stic = -17.02 P-value = 0	t-stic = -17.04 P-value = 0	t-stic = -17.32 P-value = 0
RM-rf	t-stic = -14.98 P-value = 0	t-stic = -14.92 P-value = 0	t-stic = -14.96 P-value = 0
SMB	t-stic = -17.31	t-stic = -17.34	t-stic = -17.32

[2] Corresponds to Dickey and Fuller's augmented test, a unit root test introduced by Dickey and Fuller in 1981 to identify the nature of the trend and the estimate of 3 Ar(1) models.

	P-value = 0	P-value = 0	P-value = 0
HML	t-stic = -19.69 P-value = 0	t-stic = -19.73 P-value = 0	t-stic = -19.99 P-value = 0

Source : Authors

After examining the correlogram of all the time series, we noticed that there was no significant peak at lag 1 in the ACF function, otherwise the dynamics of non-stationarity in mean and non-stationarity in variance would disappear completely.

This result is corroborated by the t-stats presented in the table above. In fact, all t-stats are strictly below their critical values at the 5% threshold, confirming the stationarity of all series.

2020 results

Table n°5: Portfolio estimates based on the market risk premium (MRP)

Portfolios	Alpha	Beta	T_sta (alpha)	prob	T_sta (beta)	prob	R2	AIC	F stati
BH	-0.0006	0.12	-0.67	0.50	1.74	0.08	0.012	-5.38	3.061
BL	-0.0003	0.17	-0.38	0.69	3.07	0.002	0.03	-5.92	9.46
SH	-0.0003	0.12	-0.57	0.56	3.06	0.0024	0.03	-6.53	9.38
SL	0.0004	0.16	0.53	0.59	2.97	0.003	0.03	-5.89	8.86

Source: Authors

In terms of the individual significance of the student's t test statistics, we see that all the probabilities corresponding to the student's t statistic of the beta coefficients are below 5%, with the exception of the BH portfolio whose critical value (1.74) is below 1.96 and whose probability is above 5%.

So all the slopes are significant except for that of the BH portfolio. Conversely, the alphas are not significant since all the probabilities are greater than 5%.

A test generally used to study overall significance is the Fisher test. According to this test, overall significance is confirmed since all F values are greater than their critical value at the 5% threshold (2.63).

The coefficients of determination are very low, ranging from 0.012 to 0.03, with an average of 0.022. The weakness of this coefficient shows the imperfect quality of the regression.

The CAPM seems ineffective and unable to explain the stock market returns of the 4 portfolios during periods of strong market turmoil.

Table n°6: Portfolio estimates based on SMB

Portfolios	Alpha	Beta	T_sta (alpha)	prob	T_sta (beta)	prob	R2	AIC	F stati
BH	**-0.0006**	**-1.77**	**-0.08**	**0.93**	**-16.73**	**0**	**0.53**	**-6.13**	**280.06**
BL	**0.0001**	**-1.38**	**0.32**	**0.74**	**-16.81**	**0**	**0.53**	**-6.65**	**282.75**
SH	**-0.0004**	**0.27**	**-0.76**	**0.44**	**3.16**	**0.001**	**0.03**	**-6.53**	**10.04**
SL	**0.0005**	**-0.43**	**0.71**	**0.47**	**-3.66**	**0.0002**	**0.05**	**-5.91**	**13.46**

Source : Authors

With regard to the individual significance of the Student's t statistics, we find that all the t statistics for the beta coefficients are greater than their critical values at the 5% threshold (1.96). This is confirmed by the probabilities associated with the Student's t statistic, which are all less than 5%. For the alphas and according to the results, we accept the null hypothesis that the alphas coefficients are not statistically different from 0, since all probabilities exceed 0.05. The overall significance test accepts the hypothesis that the model has significant explanatory power.

Coefficients of determination ranged from 0.03 to 0.53, with an average of 28% higher than previously reported. This suggests that the role played by size in explaining stock market returns exceeds that played by MRP.

Table n°7: Portfolio estimates based on HML

Portfolios	Alpha	Beta	T_sta (alpha)	prob	T_sta (beta)	prob	R2	AIC	F stati
BH	**-0.0007**	**-0.03**	**-0.69**	**0.48**	**-0.21**	**0.83**	**0.0001**	**-5.37**	**0.04**
BL	**-0.0006**	**-0.58**	**-0.86**	**0.38**	**-5.66**	**0**	**0.11**	**-6.01**	**32.10**
SH	**0.0001**	**0.60**	**-0.002**	**0.99**	**8.54**	**0**	**0.22**	**-6.75**	**73.09**
SL	**-0.00006**	**-0.83**	**-0.09**	**0.92**	**-8.50**	**0**	**0.22**	**-6.11**	**72.32**

Source : Authors

Regarding to the individual significance of the student test statistics, we note that all the t-statistics of the beta coefficients are above their critical values at the 5% threshold (1.96), except for the BH portfolio. For the alphas, we accept the null hypothesis of the student test stipulating the nullity of all alphas, given that all probabilities are greater than 5%.

The overall significance test indicates that the three portfolios SH, SL, BL play a significant role. On the other hand, the F statistical T for the BH portfolio is below its critical value of 2.63, so it has no explanatory power in the model.

As for the coefficient of determination, it fluctuates between 0.0001 and 0.22, with an average 13% lower than that of size, but even higher than that of MRP.

Table n°8: Portfolio estimates based on three factors (MRP, SMB, HML)

Portfolios	Alpha	Beta			T_sta (alpha)	prob	T_sta (beta)			prob			R2	AIC	F stati
BH	0.009	0.13	-1.81	0.22	0.13	0.88	2.72	-17.22	2.35	0.006	0	0.019	0.55	-6.16	101.12
BL	-0.0005	0.15	-1.31	-0.38	-0.10	0.92	4.31	-17.51	-5.63	0.00023	0	0	0.61	-6.83	132.72
SH	-0.005	0.15	0.18	0.61	-0.10	0.92	4.31	2.40	8.82	0	0.016	0	0.29	-6.83	34.81
SL	0.00009	0.13	-0.31	-0.77	0.13	0.88	2.72	-2.98	-7.97	0.0060	0.003	0	0.27	-6.16	30.88

Source : authors

From the results of the overall estimation, we can see that all the betas related to the three factors are significant, since the probabilities corresponding to their T-statistics are all below 5%.

For alphas, the results detect statistical T values below 1.96 and probabilities strictly above 5%.

Overall significance is confirmed by the Fisher test.

As for the coefficients of determination, the global regression shows an improvement over the individual regression.

2022 results

Table n° 9: Portfolio estimates based on the market risk premium (MRP)

Portfolios	Alpha	Beta	T_sta (alpha)	prob	T_sta (beta)	prob	R2	AIC	F stati
BH	-0.0001	1.03	-0.98	0.32	28.06	0	0.75	-9.42	787.87
BL	0.0001	0.89	0.47	0.63	14.34	0	0.45	-8.37	205.7
SH	-0.0001	0.92	-0.39	0.69	9.85	0	0.27	-7.54	97.16
SL	-0.00007	0.55	-0.20	0.83	5.77	0	0.11	-7.51	33.38

Source : authors

depending individual significance, this is confirmed for betas, given that all the probabilities of the statistical T's are zero, and invalidated for alphas, for the reason that all the probabilities associated with the statistical T's are strictly greater than 5%.

Despite the lack of significance of the alphas, overall the models are significant because the Fisher values are all above their critical value of 2.63.

Coefficients of determination ranged from 0.11 to 0.75, with an average of 39.5% well above that of 2020.

Table n°10: Portfolio estimates based on SMB

Portfolios	Alpha	Beta	T_sta (alpha)	prob	T_sta (beta)	prob	R2	AIC	F stati
BH	0.0001	-0.31	0.55	0.58	-3.70	0	0.05	-8.06	13.7
BL	0.0003	-0.53	1.11	0.26	-5.91	0	0.12	-7.90	34.93
SH	0.0002	1.04	0.73	0.46	9.42	0	0.26	-7.52	88.77
SL	0.0002	1.10	0.70	0.48	11.61	0	0.34	-7.82	134.95

Source : Authors

Estimates of the 4 portfolios as a function of SMB lead us to reject the null hypothesis for both tests. The coefficients of determination fluctuate between 0.05 and 0.34, with an average of 19.25% lower than that achieved by PRM and that recorded in 2020.

Table n° 11: Portfolio estimates based on HML

Portefeuilles	Alpha	Beta	T_sta (alpha)	prob	T_sta (beta)	prob	R2	AIC	F stati
BH	0	0.35	0.800	0.42	5.85	0	0.12	-8.13	34.27
BL	0	-0.25	1.20	0.23	-3.60	0	0.04	-7.82	12.97
SH	0.002	0.81	0.60	0.54	10.14	0	0.29	-7.56	102.95
SL	0	-0.57	0.15	0.87	-7.31	0	0.17	-7.58	53.52

Source : authors

The results marked on the table above lead us to accept the alternative Student test hypothesis that the coefficient is statistically different from 0 for betas, and to accept the null hypothesis for alphas.

This scenario requires the use of the overall significance test, according to which the null hypothesis is rejected.

As for coefficients of determination, they fluctuate between 0.04 and 0.29, with an average 15% lower than that recorded by SMB and MRP for the same year, and logically higher than that of 2020.

Table n° 12: Portfolio estimates based on three factors (MRP, SMB, HML)

Source : Authors

Estimates for the three factors for the year 2022 give us the results shown above. We validate the null hypothesis of the Student's t-test, since all the probabilities associated with the t-stats

PF	**Alpha**	**Beta**			**T_sta (alpha)**	**prob**	**T_sta (beta)**			**prob**			**R2**	**AIC**	**F stati**
BH	**-0.0001**	**0.96**	**-0.13**	**0.17**	**-0.90**	**0.36**	**27.05**	**-3.32**	**5.77**	**0**	**0**	**0**	**0.79**	**-9.56**	**316.88**
BL	**0**	**0.95**	**-0.31**	**-0.42**	**0.13**	**0.89**	**17.93**	**-5.21**	**-9.32**	**0**	**0**	**0**	**0.63**	**-8.76**	**144.15**
SH	**0**	**0.95**	**1.18**	**0.57**	**0.13**	**0.89**	**17.93**	**19.64**	**12.84**	**0**	**0**	**0**	**0.79**	**-8.76**	**313.81**
SL	**-0.0001**	**0.96**	**1.36**	**-0.82**	**-0.90**	**0.36**	**27.05**	**33.71**	**-27.24**	**0**	**0**	**0**	**0.88**	**-9.56**	**656.25**

of the beta coefficients are zero. Despite the insignificance of the alpha coefficients, overall significance is proven by Fisher's test.

The coefficients of determination range from 0.63 to 0.88, with an average of 77% well above that recorded in 2020.

Diagnostic study of residues in 2020

Table n°13: Diagnosis of residuals from estimates of 4 portfolios as a function of market risk premium (MRP)

Portfolios	Autocorrelation		Homoscedasticity		Normality	
	R*obs	Proba	R*obs	Proba	JB	Proba
BH	4.400390	0.1108	6.752348	0.0094	1384.96	0
BL	3.449152	0.1782	2.590018	0.1075	982.70	0
SH	0.917968	0.6319	1.694883	0.1930	47.21	0
SL	2.740501	0.2540	4.205043	0.0403	1114.49	0

Source : Authors

After examining the correlogram of the residuals of all the portfolios, we found that all the probabilities are greater than 0.05, so no stick crossed the dotted lines, showing the absence of auto-correlation of the residuals. This observation can be reinforced by the Ljung Box test shown in the table above, whose corresponding probability for each portfolio is strictly greater than 5%.

Using the ARCH test to ascertain the stability of the amplitudes around the mean, we found that only the BL and SH portfolios have probabilities greater than 0.05, so their residuals are homoscedastic.

As for normality, it is rejected since all probabilities are strictly less than 5%.

Table n°14: diagnosis of the residuals of the estimates of the 4 portfolios as a function of SMB

Portfolios	Autocorrelation		Homoscedasticity		Normality	
	R*obs	Proba	R*obs	Proba	JB	Proba
BH	1.055475	0.5899	8.054400	0.0045	431.69	0
BL	10.03803	0.0066	17.62064	0.0000	204.33	0
SH	4.669798	0.0968	0.153613	0.0155	60.63	0
SL	0.624271	0.7319	13.76642	0.0002	452.99	0

Source : Authors

Given the absence of autocorrelation, we note that this hypothesis is rejected for the BL portfolio, while the other two hypotheses, normality and homoscedasticity, are rejected for the residuals of the 4 portfolios, given their low probabilities, which do not exceed 5%.

Table n°15: diagnosis of residual estimates for the 4 portfolios as a function of HML

Portfolios	Autocorrelation		Homoscedasticity		Normality	
	R*obs	Proba	R*obs	Proba	JB	Proba
BH	3.352341	0.1871	6.826913	0.0090	1281.58	0
BL	8.743663	0.0126	3.857791	0.0495	763.93	0
SH	9.127435	0.0104	12.59764	0.0004	84.49	0
SL	2.070924	0.3551	9.074096	0.0026	1024.29	0

Source : Authors

Diagnosis of the residuals of the estimates of the 4 portfolios as a function of HML reveals that the hypothesis of the absence of autocorrelation is verified only for the two portfolios BH and SL. As for heteroscedasticity, it is accepted for all 4 portfolios. As before, normality is always rejected.

Table n°16: Diagnosis of residual estimates for the 4 portfolios as a function of three factors (PRM, SMB, HML)

Portefeuilles	Autocorrelation		Homoscedasticity		Normality	
	R*obs	Proba	R*obs	Proba	JB	Proba
BH	2.577295	0.2756	4.376629	0.0364	592.80	0
BL	3.671257	0.1595	0.023069	0.8793	172.45	0
SH	3.671257	0.1595	0.023069	0.8793	172.45	0
SL	2.577295	0.2756	4.376629	0.0364	592.80	0

Source : Authors

Diagnosis of the residuals of the estimates of the 4 portfolios as a function of three factors once again attests to the rejection of the normality hypothesis, since all the statistical T values are above their critical values of 5.99.

As for the absence of auto-correlation, all probabilities are greater than 5%, so the residuals are not auto-correlated.

With regard to the last property, the results show that the residuals of the 2 BL and SH portfolios are homoscedastic, while the other two are heteroscedastic.

Diagnostic study of residues in 2022

Table n°17 : Diagnosis of residuals from estimates of 4 portfolios as a function of MRP

Portefeuilles	Autocorrelation		Homoscedasticity		Normality	
	R*obs	Proba	R*obs	Proba	JB	Proba
BH	6.159133	0.0460	10.26050	0.0014	6.01	0.049
BL	26.14533	0.0000	1.858116	0.1728	4.41	0.10
SH	6.934513	0.0312	3.591552	0.0581	17.54	0
SL	7.012809	0.0300	2.059018	0.1513	9.90	0

Source : Authors

Diagnosis of the residuals from the estimates of the 4 portfolios as a function of PRM reveals that the hypothesis of no autocorrelation is rejected for all residuals.

Heteroscedasticity is verified for the BH portfolio, since the ARCH test statistic is above its critical value, while the other residuals are homoscedastic.

Unlike the other diagnoses, normality is confirmed for the BL portfolio, since its JB is strictly below the critical chi-square value at 95% (5.99). Clearly, the corresponding probability is 0.10 and therefore well above 0.05, and we can therefore conclude that it Ya a normality.

Table n°18: diagnosis of the residuals of the estimates of the 4 portfolios as a function of SMB

Portefeuilles	Autocorrelation		Homoscedasticity		Normality	
	R*obs	Proba	R*obs	Proba	JB	Proba
BH	7.402216	0.0247	7.121239	0.0076	350.86	0
BL	0.399412	0.8190	0.162941	0.6865	18.42	0
SH	10.47834	0.0053	5.690936	0.0171	77.94	0
SL	1.791011	0.4084	0.167496	0.6823	20.01	0

Source : Authors

The residuals and squared residuals of the BL and SL portfolios are independent, as revealed by the probabilities associated with the statistical T's provided by the LB test and the probabilities associated with the statistical T's provided by the ARCH test.

All JB's T-statistics are strictly above the critical 95% chi-square value (5.99), so the residuals are not normally distributed.

Table n°19: diagnosis of residual estimates for the 4 portfolios as a function of HML

Portefeuilles	Autocorrelation		Homoscedasticity		Normality	
	R*obs	Proba	R*obs	Proba	JB	Proba
BH	1.291959	0.5241	2.135386	0.1439	150.6	0
BL	1.519201	0.4679	0.549537	0.4585	30.73	0
SH	0.779883	0.6771	5.090789	0.0241	8.90	0
SL	2.155162	0.3404	5.217168	0.0224	32.08	0

Source : Authors

According to the estimates of the 4 portfolios based on HML, the hypothesis of the absence of autocorrelation is strongly accepted, since all probabilities are greater than 5%. As for the stability of amplitudes over time, this is verified for the residuals of the BH and BL portfolios. Normality is rejected for all residuals.

Table n°20: Diagnosis of residual estimates for the 4 portfolios as a function of three factors (MRP, SMB, HML)

Portefeuilles	Autocorrelation		Homoscedasticity		Normality	
	R*obs	Proba	R*obs	Proba	JB	Proba
BH	4.148642	0.1256	8.129175	0.0044	3.76	0.15
BL	26.37022	0.0000	3.029446	0.0818	1.75	0.41
SH	26.37022	0.0000	3.029446	0.0818	1.75	0.41
SL	4.148642	0.1256	8.129175	0.0044	3.76	0.15

Source : Authors

From the results, it is clear that with JB values well below the critical value of 5.99, it is clear that the probabilities corresponding to the null hypothesis of normality are all well above 0.05, so we can conclude that there is normality.

The residuals are dependent for both the BL and SH portfolios, and the squared residuals are dependent for both the BH and SL portfolios.

By conducting a univariate analysis for the year 2020, we report the robustness of the size factor ahead of the other two factors for both large-cap portfolios.

For its part, the BTM ratio stands out from the other two factors for both small-cap portfolios. As far as MRP is concerned, it appears to be the most mediocre factor.

If we proceed to rank the factors in predicting stock market returns, the ranking will be as follows: size will occupy first place, followed by the BTM ratio and lastly PRM. It should be noted that the presence of all three factors in a single model enhances the predictive quality of each.

The univariate analysis carried out on 2022 data revealed that, unlike 2020, the MRP was exceptional in explaining stock market returns for both large-cap portfolios.

For high-cap portfolios, the BTM ratio speaks for itself in determining stock market returns. For small-cap portfolios, the size factor reigns supreme.

Based on these results, the ranking of the 3 factors can take the following form: MRP came first, then the size factor came second and finally the BTM ratio. The presence of all three factors in a single model makes the predictive quality of each effective compared to the uni-factorial case.

The multi-variate analysis enabled us to draw a number of conclusions. Indeed, the interesting differences between the SH portfolio determination coefficient in 2022 and 2020 and the SL portfolio determination coefficient in 2022 and 2020 attest to the inability of the size factor to correctly reflect stock market returns in 2020, which is quite normal given the high volatility experienced by the market in that year. On the other hand, this factor stands out in 2022, a less turbulent period than 2020.

In the case of the BH and BL portfolios, there is no great difference in the coefficient of determination for the two periods, suggesting that size is the key to determining returns even in periods of high volatility.

Conclusion

In conclusion, an in-depth analysis of the residuals and parameters resulting from the estimation of the Fama & French model for the years 2020 and 2022 reveals significant nuances in its performance, highlighting a moderate adaptation to opposing economic conditions.

During the health crisis of 2020, which had economic repercussions, the Fama-French model showed notable resilience. The absence of autocorrelation in the residuals testifies to its ability to quickly adjust yield forecasts in response to unpredictable economic fluctuations.

Nevertheless, the variations in homoscedasticity and the rejection of normality in the residuals highlight the specific problems posed by increased volatility and unusual market patterns during this period of volatility.

In contrast to the observations made for the year 2020, the year 2022, characterized by relative economic stability, highlights a significantly different dynamic within the Fama-French model. The detection of a residual autocorrelation suggests a particular reaction of the model to more predictable and constant economic conditions. This detection could be interpreted as an indication of the model's resistance to anticipating temporal evolutions in contexts where trends are less subject to significant fluctuations.

Despite the persistence of some variations in the homoscedasticity of the residuals, this result suggests that the model retains good robustness in understanding volatility variations, even in relatively stable economic periods. In particular, the signs of normality, particularly pronounced for the BL portfolio, suggest a better adaptation of the model to financial contexts characterized by lower volatility. These indications suggest that the model may express a greater ability to produce reliable estimates when economic conditions are less prone to abrupt fluctuations, underlining its potential effectiveness in more consistent and predictable financial environments.

Overall, these observations clearly underline that the Fama-French model performs better outside crisis periods, where the stability of residuals indicates better asset predictability. This distinct ability of the model to provide more reliable estimates under more stable economic conditions reinforces its relevance as the preferred valuation tool in less volatile financial environments. Thus, the results of the residual analysis confirm the model's ability to adapt with discernment to variations in the economic environment, underlining its particular effectiveness in periods of stability.

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