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Analysis Stock Risk Factors Following Fama and French (1993)

1. Introduction

This study aims to replicate and extend the results obtained by Fama and French (1993). The researchers analyzed several risk factors to predict stock returns. Their results extended the area of finance, which was dominated by capital asset pricing model. But significant time elapsed since the work of the researchers, and the study aims to check if the relevance of the suggested risk factors remains still relevant.

The key research questions therefore are the following: What is the importance of the results by Fama and French (1993)? Is relevance of the risk factors suggested by Fama and French (1993) still high after year 1991 as it was in the period 1963- 1991? Was there a structural break in relation to the recent global financial crisis?

Structure of this analysis is as follows. Section 2 provides the analysis of relevant literature in the realm of the asset pricing models and arbitrage-pricing theory. Section 3 describes the replication methodology and also methodological issues for extension of the study by Fama and French (1993). The obtained empirical results are presented in section 4. Finally, section 5 concludes with the summary of key findings.

2. Literature Review

The study by Fama and French (1993) was in the realm of financial asset pricing models. For decades the area was dominated by capital asset pricing model that was based on portfolio theory developed by Markowitz (1952). The Markowitz (1952) study established the inverse relation between expected return and risk, and more importantly established the portfolio diversification feature, relating to the decreasing volatility of portfolio returns as the number of stocks in the portfolio increases.

Capital asset pricing model was developed by Sharpe (1964) and Lintner (1965). The model assumed independent normal distribution of stock returns , perfect information on the stock market. Under the state assumptions return on a given stock is closely explained by the market premium, being a difference between return on the market portfolio and risk-free rate, and stock-specific beta parameter: $Ri = Bi(Rm - Rf) + e$. The model was then broadly adopted by academic researchers and finance practitioners in different areas of finance. For instance it is used until nowadays in corporate finance to help estimate cost of equity capital (Bodie et al., 2011).There were quite a number of empirical tests of CAPM, which nevertheless could not be completely conclusive. And general critique was that it is not possible to robustly test CAPM (Bodie et al., 2011).

Contribution of Fama and French (1993) is towards the arbitrage pricing theory. The theory assumes that all assets are fairly priced and there cannot be arbitrage opportunities. Then any relative differences in stock prices are related to differences in their risk. Fama and French (1993) suggested two more factors, in addition to the market premium (Rm-Rf), for stock pricing. The two other factors are 'SMB' and 'HML'. Where, SMB is the excess return on small companies versus big companies, and HML is the excess returns for companies with high book to market ratio versus those with low book to market ratios. Their results proved to contribute towards higher explanatory power of the asset pricing model. Fama and French (1993) also came up with two factors for bond pricing, which are not considered in this project. In 2015 the model was developed into five-factor model, as researchers added two more factors, namely profitability and investment factor (Fama and French, 2015). But the explanatory power of the model seem not to change much.

Subsequently the model by Fama and French (1993) was also widely adopted in the corporate finance area, although its use is much narrower compared to that of CAPM, mainly because of higher complexity of the model compared to CAPM.

3. Methodology

1. Data

Relevant data includes the monthly frequency returns on a number of different portfolios. In fact, there was data on 25 portfolios classified by the market capitalization as well as book to market ratio of the underlying companies. In addition, there were data on the excess market return, as well as return on risk-free rate, and the excess return on small firms versus big firms, and excess return on firms with high book to market ratio versus those with low book to market ratio.

The time-span of the data covers the time period from July 1963 till October 2016. The sub-period of July 1963 – December 1991 was included into the original study by Fama and French (1993), and the second part was used for extension of the results. The described data was obtained from Kenneth French Data Library[1].

2. Estimation methodology

The model of Fama and French (1993) determines the return on a given stock *i* as the function of three risk factors – the excess market return, the SMB factor and HML factor. With SMB being the excess return on small versus big firms, and HML is the excess return on stocks with high book to market value over those with low book to market values.

$$R_i = \beta_i(R_m - R_f) + s_i SMB + h_i HML + \varepsilon_i \quad (1)$$

Equation (1) is in fact time-series model that is estimated for one stock i at a time. For the sae of simplicity subscript '*t*' is omitted.

SMB and HML factors were computed Fama and French (1993) empirically period-by-period in the following way. Factor SMB was computed for each month as the difference of the average return on the portfolio of stocks in the lowest quintile and those in the highest quintile by the stock market capitalization. Also, factor HML was determined for each period as the difference between the return

[1] Kenneth French Data Library, available at: http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html

on portfolio of stocks in the top quintile and those in the bottom quintile based on the book to market ratio[2] .

3. Extensions

The results by Fama and French (1993) are extended in several ways. Firstly, most straightforwardly, the analysis is extended in time. The initial dataset of Fama and French (1993) included 342 monthly periods, which was extended to include 298 monthly periods more in this study. Secondly, the analysis in this study performs structural break analysis to investigate whether the model parameters changes in a significant manner over time and in particular after the global financial crisis of 2007 - 2008.

4. Analysis of Results

The presented results include summary statistics of dependent and explanatory variables (table 2), the estimation results for capital asset pricing model (table 3), the estimation results for Fama-French (1993) three –factor model (table 6), as well as structural break testing results (table 7).

Each of the tables 2, 3 and 6 is performed for the original time period (so that it can be compared to the original study by Fama and French (1993), and also for the subsequent period from January 1992 till October 2016. Thus the results can be compared between the two time periods. The testing for structural break was not implemented in the original paper by Fama and French (1993).

Descriptive statistics (table 2) indicates that in sub-period 1 factors SMB and HML were more significantly greater than zero, there was higher first –order autocorrelation in these factors, as well as they were more highly correlated with Rm-Rf factor.

Table 3 suggests that CAMP on its own has high explanatory power, with risk loadings (Betas) being higher for smaller firms with lower book to market values. Table 6 generally indicates improved explanatory power compared to CAPM. Factor HML became more relevant in 1992-2016 sub-period.

[2] Book-to-market ratio is the ratio of the balance sheet value of equity to stock market capitalization (Bodie et al., 2011)

Table 2 (*Replication*)

Summary statistics for the monthly dependent and explanatory returns (in percent): July 1963 to December 1991, 342 months

Name	Mean	Std.	t(mn)	Autocorr. for lag 1	Autocorr. for lag 2	Autocorr. for lag 12	Correlations		
Explanatory returns									
							RM - RF	SMB	HML
RM – RF	0.410	4.599	1.648	0.071	-0.046	0.023	1.000		
SMB	0.269	2.884	1.726	0.165***	0.019	0.205***	0.369	1.000	
HML	0.395	2.561	2.854	0.175***	0.032	0.088*	-0.368	-0.098	1.000

Dependent variables: Excess returns on 25 stock portfolios formed on ME and BE/ME *Book-to-market equity (BE/ME) quintiles*										
Size quintile	Low	2	3	4	High	Low	2	3	4	High
	Means					St. dev				
Small	.297	.667	.715	.890	1.001	7.793	6.808	6.284	5.926	6.303
2	.394	.654	.855	.917	.998	7.328	6.290	5.730	5.377	6.029
3	.430	.700	.644	.844	.929	6.697	5.730	5.193	4.947	5.700
4	.451	.358	.627	.780	.882	5.924	5.446	5.103	4.920	5.678
Big	.372	.336	.342	.521	.520	4.908	4.706	4.366	4.355	4.776
	t-stats									
Small	0.706	1.812	2.106	2.777	2.939					
2	0.994	1.925	2.761	3.155	3.063					
3	1.187	2.260	2.295	3.156	3.016					
4	1.410	1.2162	2.273	2.933	2.873					
Big	1.402	1.320	1.449	2.214	2.016					

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

Table 2 (*Extension*)

Summary statistics for the monthly dependent and explanatory returns (in percent): January 1992 to October 2016, 298 months

Name	Mean	Std.	t(mn)	Autocorr. for lag 1	Autocorr. for lag 2	Autocorr. for lag 12	Correlations		
Explanatory returns									
							RM - RF	SMB	HML
RM – RF	0.608	4.234	2.480	0.079	-0.042	0.032	1.000		
SMB	0.163	3.306	0.851	-0.089	0.012	0.001	0.216	1.000	
HML	0.312	3.06	1.761	0.149**	0.002	-0.023	-0.161	-0.311	1.000
Dependent variables: Excess returns on 25 stock portfolios formed on ME and BE/ME *Book-to-market equity (BE/ME) quintiles*									
Size quintile	Low	2	3	4	High	Low	2	3	4	High
	Means					St. dev				
Small	0.133	0.883	0.819	1.095	1.173	8.102	7.035	5.622	5.407	5.628
2	0.531	0.834	0.878	0.912	0.970	7.049	5.589	5.041	5.003	6.039
3	0.543	0.857	0.856	0.894	1.132	6.488	5.140	4.764	4.827	5.525
4	0.744	0.840	0.762	0.926	0.727	5.879	4.691	4.821	4.619	5.661
Big	0.572	0.708	0.750	0.441	0.804	4.269	4.077	4.184	4.923	5.946
	t-stats									
Small	0.285	2.168	2.516	3.498	3.599					
2	1.300	2.576	3.009	3.146	2.774					
3	1.446	2.880	3.104	3.199	3.538					
4	2.187	3.093	2.729	3.461	2.217					
Big	2.314	3.001	3.094	1.547	2.333					

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

Table 3 (Replication & Extension)

Regressions of excess stock returns (in percent) on the excess market return (RM-RF)

Replication: July 1963 to December 1991, 342 months

Extension: January 1992 to October 2016, 298 months

$$R(t) - RF(t) = a + b[RM(t)-RF(t)] + e(t)$$

Dependent variable: Excess returns on 25 stock portfolios formed on size and book-to-market equity

	Book-to-market equity quintiles					Book-to-market equity quintiles				
	Replication					*Extension*				
Size Quintile	Low	2	3	4	High	Low	2	3	4	High
			b					*b*		
Small	1.420	1.244	1.150	1.068	1.102	1.432	1.228	1.046	0.958	1.017
2	1.430	1.225	1.109	1.035	1.121	1.364	1.104	0.983	0.974	1.131
3	1.353	1.158	1.030	0.973	1.068	1.290	1.072	0.978	0.941	1.045
4	1.222	1.128	1.038	0.969	1.084	1.235	1.000	0.980	0.930	1.090
Big	1.001	0.978	0.861	0.848	0.860	0.948	0.881	0.827	0.929	1.088
			R^2					R^2		
Small	0.700	0.704	0.706	0.684	0.643	0.558	0.545	0.620	0.562	0.584
2	0.803	0.800	0.789	0.781	0.728	0.670	0.699	0.681	0.679	0.628
3	0.861	0.861	0.830	0.816	0.740	0.708	0.780	0.755	0.681	0.641
4	0.898	0.905	0.873	0.817	0.768	0.791	0.815	0.740	0.727	0.663
Big	0.877	0.912	0.820	0.799	0.683	0.885	0.837	0.699	0.637	0.599

** All coefficients in the table are significant at 1% level*

Table 6 (Replication)

Regressions of excess stock returns (in percent) on the excess market return (RM-RF) and the mimicking returns for the size (SMB) and book-to-market factors: July 1963 to December 1991, 342 months

$$R(t) - RF(t) = a + b[RM(t)-RF(t)] + sSMB(t) + hHML(t) + e(t)$$

Dependent variable: Excess returns on 25 stock portfolios formed on size and book-to-market equity

Book-to-market equity quintiles

Size Quintile	Low	2	3	4	High	Low	2	3	4	High
			b					*s*		
Small	1.035***	0.966***	0.935***	0.891***	0.952***	1.407***	1.274***	1.160***	1.103***	1.189***
2	1.100***	1.015***	0.961***	0.968***	1.067***	1.002***	0.932***	0.844***	0.707***	0.850***
3	1.102***	1.022***	0.968***	0.971***	1.062***	0.703***	0.622***	0.542***	0.452***	0.648***
4	1.061***	1.071***	1.043***	1.033***	1.152***	0.301***	0.267***	0.249***	0.225***	0.356***
Big	0.956***	1.019***	0.963***	1.007***	1.024***	-0.200***	-0.194***	-0.261***	-0.190***	-0.040
			h					R^2		
Small	-0.287***	0.079**	0.262***	0.384***	0.612***	0.938	0.957	0.965	0.964	0.963
2	-0.478***	0.029	0.234***	0.471***	0.699***	0.956	0.958	0.958	0.955	0.957
3	-0.428***	0.039	0.310***	0.499***	0.703***	0.959	0.947	0.931	0.938	0.927
4	-0.445***	0.023	0.307***	0.566***	0.733***	0.946	0.922	0.912	0.910	0.895
Big	-0.445***	-0.021	0.201***	0.564***	0.757***	0.937	0.924	0.855	0.904	0.824

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

Table 6 (Extension)

Regressions of excess stock returns (in percent) on the excess market return (RM-RF) and the mimicking returns for the size (SMB) and book-to-market factors: January 1992 to October 2016, 298 months

$$R(t) - RF(t) = a + b[RM(t)-RF(t)] + sSMB(t) + hHML(t) + e(t)$$

Dependent variable: Excess returns on 25 stock portfolios formed on size and book-to-market equity

Book-to-market equity quintiles

Size Quintile	Low	2	3	4	High	Low	2	3	4	High
			b					*s*		
Small	1.163***	0.997***	0.907***	0.836***	0.931***	1.341***	1.351***	1.018***	1.043***	0.998***
2	1.157***	0.979***	0.915***	0.928***	1.079***	1.004***	0.859***	0.727***	0.706***	0.936***
3	1.116***	1.022***	0.972***	0.957***	1.069***	0.762***	0.495***	0.356***	0.389***	0.478***
4	1.112***	1.003***	1.019***	0.966***	1.156***	0.484***	0.193***	0.141***	0.171***	0.188***
Big	0.959***	0.933***	0.909***	1.044***	1.215***	-0.264***	-0.198***	-0.220***	-0.228***	-0.147***
			h					R^2		
Small	-0.293***	0.042	0.303***	0.483***	0.716***	0.887	0.920	0.933	0.925	0.933
2	-0.308***	0.189***	0.491***	0.627***	0.881***	0.935	0.926	0.905	0.931	0.949
3	-0.422***	0.255***	0.483***	0.656***	0.833***	0.935	0.874	0.864	0.859	0.857
4	-0.358***	0.314***	0.524***	0.544***	0.805***	0.925	0.858	0.841	0.844	0.835
Big	-0.334***	0.184***	0.403***	0.693***	0.805***	0.952	0.893	0.842	0.876	0.794

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

Table 7 (Extension)

Test for structural break in June 2008 (placebo test: 1995, 2000, 2005)

R(t) – RF(t) = a + b[RM(t)-RF(t)] + sSMB(t) + hHML(t) + e(t)

Ho: No structural break

	Prob (chi2)					*Prob (chi2)*				
Size Quintile	Low	2	3	4	High	Low	2	3	4	High
	Date of break: June 2008					*Date of break: June 2000*				
Small	0.077	0.286	0.055	0.312	0.774	0.522	0.001	0.797	0.176	0.721
2	0.108	0.000	0.000	0.000	0.471	0.547	0.012	0.000	0.001	0.061
3	0.695	0.000	0.000	0.000	0.000	0.450	0.180	0.000	0.003	0.000
4	0.700	0.000	0.000	0.000	0.019	0.016	0.000	0.009	0.144	0.248
Big	0.148	0.000	0.000	0.107	0.141	0.000	0.497	0.000	0.755	0.495
	Date of break: June 1995					*Date of break: June 2005*				
Small	0.511	0.245	0.132	0.503	0.177	0.094	0.058	0.018	0.064	0.231
2	0.215	0.037	0.067	0.250	0.020	0.097	0.000	0.000	0.000	0.486
3	0.060	0.284	0.127	0.129	0.528	0.528	0.000	0.000	0.000	0.000
4	0.270	0.127	0.305	0.018	0.370	0.410	0.000	0.000	0.000	0.006
Big	0.001	0.515	0.228	0.105	0.269	0.013	0.000	0.000	0.148	0.284

5. Conclusion

In conclusion it can be re-stated that the results of Fama and French (1993) added considerably towards the explanatory power of asset pricing model. This is observed by the higher coefficient of determination for the latter versus the former model.

The additional analysis in this study showed that the relevance of the three risk factors remains high for explaining he stock returns. Besides, testing for structural break suggested that the risk loadings (e.g. stock-specific coefficients *B*, *s*, and *h*) are rather unstable and change with time.

Future analysis could investigate the relevance of these and other factor on industry basis. Moreover, relevance of these factors can be compared based on various frequencies of data – e.g. daily versus weekly versus monthly frequency.

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