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THE ANALYSIS OF AN INVESTMENT RISK WITHIN EMERGING CAPITAL MARKETS. THE CASE OF THE WARSAW STOCK EXCHANGE

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Abstract

The purpose of the paper is to show that the three-factor Fama-French model can be a good instrument for analysis of investment risk on emerging capital markets if, because of the relatively small number of quoted companies, for calculation of the SMB and HML values we applied division of all companies into four portfolios (contrary to Fama – French who propose division of all companies into six portfolios). The usefulness of the above concept was verified on the Warsaw Stock Exchange.

The models estimated with the Generalized Least Squares Method on monthly data within the period 1994 – 2008 have the signs of coefficients which are consistent with those of the Fama-French three-factor model and there is no autocorrelation of disturbances and no ARCH effect. Models are relatively high adjusted. Estimated coefficients are also robust.

The models fully confirm the thesis posed by Fama and French that in addition to market risk there are two other risk factors which influence the return on investment. These are: risk associated with investing in small companies and risk connected with investing in companies undervalued by the market.

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Introduction

The Capital Asset Pricing Model (CAPM) created in the 1960s, (Lintner, 1965; Mossin, 1966; Sharpe, 1964), was considered for a long time the

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best asset pricing instrument. Its reputation has been confirmed by the results of empirical research on New York Stock Exchange data for the 1926-1969 period, conducted independently by Fischer Black, Michael Jensen and Myron Scholes (1972), and Eugene Fama and James McBeth (1973). The results of their research showed a strong relationship between an average return and the risk measured with the beta coefficient. However, at the beginning of the 1980s, some researchers published the empirical results which showed that the average returns depend not only on the market risk but also on the different characteristics of companies listed on the stock exchange. Sanjoy Basu (1977, 1983) showed that the average returns depend on the earnings-price ratios. Ralf Banz (1981) proved that the companies with low capitalization bring higher returns than the companies with high capitalization. The results were also confirmed by Marc Reinganum (1981).

The proponents of the CAPM model and the effective capital market theory have called such situations anomalies, and by doing so claimed that these are only chance divergences from the major assumptions of the theory. At the same time, the opponents of the theory maintain that the results above deny the theory (Haugen, 1995).

Inspired by the results of research, Eugene Fama and Kenneth French (1992) decided to analyse the data for the 1963-1990 period and arrived at the conclusion that there were two easily measured variables; Market Equity-size (ME) and Book Equity to Market Equity (BE/ME), which can explain a considerable part of the average return variability. Small companies have higher returns than big ones, while the companies with the high book-to-market equity ratios bring higher returns than those of low book-to-market equity ratios.

The companies with low capitalization as well as the companies with the high book-to-market equity ratios (undervalued by the market) also called the "firms with value potential" (Haugen, 1995), tend to be the companies that are weak when it comes to their earnings and sales, and whose capital is badly managed. Even though their situation may radically improve in the future, investing in such companies is more risky than investing in the big companies (well-valued by the market), also called the "firms with growth potential" (Haugen, 1995).

The above observations made E. Fama and K. French (1993) define the fundamental idea of the CAPM model, that returns depend on the risk and thus lead them to create the three-factor model in which they included a multidimensional risk, i.e. in addition to the market risk, they introduced two other dimensions of risk: the risk of investing in small companies and the risk of investing in the companies in which the market equity is low compared to the book equity. The Fama-French model is as follows:

$$R_i - R_f = a_i + b_i(R_M - R_f) + s_i SMB + h_i HML + \varepsilon_i \quad (1)$$

where
- R_i – the return on asset of i – th portfolio
- R_f – the risk-free rate
- $R_i - R_f$ – the excess return of i – th portfolio
- R_M – the market return
- SMB – (**S**mall **M**inus **B**ig) - the difference between the returns on the portfolios of small stocks and the portfolios of big stocks which is the measure of risk associated with investing in small companies
- HML – (**H**igh **M**inus **L**ow) - the difference between the returns on the portfolios of high BE/ME stocks and the returns on the portfolios of low BE/ME stocks which is the measure of risk associated with investing in the undervalued companies
- b_i – the market risk price for *i*-th portfolio; the product of $b*R_M$ is the market premium
- s_i – the risk price for *i*-th portfolio associated with investing in small companies; the product of s*SMB is the premium for investing in small companies – size premium
- h_i – the risk price for *i*-th portfolio associated with investing in the undervalued companies; the product of h*SMB is the premium for investing in the undervalued stocks – value premium[2].

[2] In other words, parameters b_i , s_i , h_i defines sensitivity of i – th portfolio to particular risks (Szyszka, 2003, p. 94).

Fama and French have divided the companies into two groups considering their size and into three BE/ME groups in order to calculate SMB and HML. The companies whose market value was above the median of the market capitalization were placed in the portfolio of big companies (B), while the remaining companies belonged to the portfolio of small companies (S). The companies whose BE/ME value corresponded with the bottom 30% of BE/ME for all the companies listed on the stock exchange were placed in the portfolio of low book-to-market equity ratio (L). The next group (M) constituted he middle 40% of the companies. The last group (H) consisted of the companies with the highest BE/ME ratio. Based on this division six portfolios were formed: S/L, S/M, S/H, B/L, B/M, B/H. The capitalization of the portfolios has been used to calculate the monthly returns.
SMB is the difference between the arithmetic mean from the returns on three portfolios of small companies and the mean from the returns on three portfolios consisting of big companies:

$$SMB = (S/L + S/M + S/H)/3 - (B/L + B/M + B/H)/3 \quad (2)$$

Similar calculations are made to find out the value of HML:

$$HML = (S/H + B/H)/2 - (S/L + B/L)/2 \quad (3)$$

where S/L – the monthly return on the portfolio of small companies with low BE/ME ratio (small companies highly valued by the market)
S/M – the monthly return on the portfolio of small companies with middle BE/ME ratio
S/H – the monthly return on the portfolio of small companies with high BE/ME ratio (small companies lowly valued by the market)
B/L – the monthly return on the portfolio of big companies with low BE/ME ratio (big companies highly valued by the market)
B/M – the monthly return on the portfolio of big companies with middle BE/ME ratio

B/H – the monthly return on the portfolio of big companies with high BE/ME ratio (big companies lowly valued by the market)

Firstly, E. Fama and K. French (1993) estimated the model for the 1963-1991 period using the data from NYSE, AMEX and NASDAQ. Next, they repeated their analysis several times by extending the time series as well as including more data from other developed capital markets (Fama & French, 1998). The most complete analysis refers to the period from July 1929 to June 1997 (Davis, Fama, & French, 2000).

The models estimated by E. Fama and K. French confirmed the hypothesis that in addition to for the market risk there are two other underlying risk factors which influence the average return variability. These are: the risk associated with investing in small companies and the risk connected with investing in the companies undervalued by the market.

Moreover, E. Fama and K. French (1996) demonstrated that the three-factor model explains most of the anomalies related to the different characteristics of companies (earnings/price, cash flow/price, market leverage, past five – year sales growth) as well as the winner-loser effect in the long run.

The three-factor model, together with the SMB and HML explanatory variables became in time one of the basic instruments in both developed and emerging capital market studies.

The first Fama-French three-factor models were estimated for the Warsaw Stock Exchange for the 1996-2006 period (Kowerski, 2008). The three-factor models of excess returns confirmed that also on the Warsaw Stock Exchange the returns on investments are affected not only by the market risk, but also by the risks associated with investing in small companies and the companies undervalued by the market. However, those models were poorly adjusted in comparison with the models for the developed capital markets. The adjusted coefficients of determination fluctuated from 0,60 to 0,93 depending on the portfolio while the adjusted determination coefficients in the models estimated for the New York Stock Exchange for the 1963-1997 were between 0,91 and 0,98 (Davis, Fama, & French, 2000). Another important drawback for one of the

portfolios constituted the statistically significant positive constant coefficient which indicates the possibility of gaining risk-free additional earnings.
It is undoubtedly the consequence of the much shorter time series but most of all it results from the smaller number of companies included in the particular portfolios. This consequently leads to the significant fluctuations of returns, especially in the portfolios of small companies, and to the high correlations of variables SMB and HML.
Therefore, a hypothesis was created that when the number of companies is as small as on the Warsaw Stock Exchange, only four portfolios should be created, and considering their book-to-market equity ratio the companies should be placed into two groups [3].
The objective of this paper is to verify the above hypothesis. In addition to this, extending the time series to 2008, i.e. to the beginning of the present recession, should reveal how responsive the three-factor model is to the economic cycle.

The data and the methodology of creating three-factor models for the Warsaw Stock Exchange

The three-factor models for the Warsaw Stock Exchange were created in accordance with the methodology suggested by E. Fama and K. French. This means that in order to be taken into consideration during the classification procedure (the grouping into particular portfolios), the companies had to have positive book equity and be listed on the stock exchange for the nearest year. The data for calculations came from the Stock Market Quotation[4].
The first classification of the companies took place at the end of June 1994, and the last one at the end of June 2007. In all there were 14 classification procedures. The companies were grouped into four portfolios (instead of six) which constituted an element of innovation.

[3] The thesis departs from the present direction of research on developed markets where grouping into more than six portfolios is suggested because of growing diversity among the listed companies. Also Fama and French together with Davis (2000) suggested grouping companies into nine portfolios.
[4] www.gpw.com.pl.

Because of their capitalization, the companies were arranged in a rising order and those whose capitalization was below the median were put into the portfolio of small companies (S) while those with capitalization above the median created the portfolio of big companies (B). If there was an odd number of companies, the company whose capitalization was equal to the median was included in the portfolio B.
Following this procedure, four portfolios were created:

S/L – small companies highly valued by the market
S/H – small companies lowly valued by the market
B/L – big companies highly valued by the market
B/H – big companies lowly valued by the market

The next step was to calculate the monthly excess returns for each of the four portfolios in each month as well as the SMB and HML variables. It is important to notice that because of dividing companies into only two groups, the formula for calculating the SMB variable was modified:

$$SMB=(S/L+S/H)/2-(B/L+B/H)/2 \quad (4)$$

In the present analysis, the main index of the Warsaw Stock Exchange (WIG) was assumed to be representative of the whole market and the monthly average calculated from the 12-month treasury bill yield was assumed to be the risk-free rate.
During the period of 14 years, 168 observations were made (12 observations each year) which resulted in the series of monthly returns on the portfolios and the series of SMB and HML variables[5].
Since half of the models which have been estimated with the Least Squares Method were characterized by the heteroscedastisity of disturbances, the parameters were estimated with the Generalized Least Squares Method.
In order to analyze the robustness of the estimated parameters, the models based on shorter time series were also created. Ten models were built for each of the portfolios – starting from the model for the period from July

[5] Calculations of values of all variables were done by Jerzy Kot from the University of Management and Administration in Zamość.

1994 to June 1999 (60 observations), then for the period from July 1994 to June 2000 (72 observations), and finally the model for the whole period in question (168 observations).

The number of companies on the Warsaw Stock Exchange is increasing but it is still a small stock exchange. The overall number of companies which were included in the portfolios was on the increase in two periods - from 1994 to 2001 and from 2004 to the end of the period in question, while between 2001 and 2004 the general number of companies has fallen. During the period covered by the present analysis the number of companies averaged 168.

When compared with the Fama and French's research, the number of companies in the portfolios is relatively small (especially in the portfolios S/L and B/H). The portfolios S/H and B/L included the biggest number of companies, even though the average number of companies in these portfolios (54) was not big. Considering the number of companies constituting the portfolios, the structure of portfolios was rather stable - the share of the most numerous portfolios S/H and B/L ranged from c. 30% to 35% (32,19% on average), while the shares of the least numerous ones S/L and B/H were on average 17,69% and 17,94% respectively.

Taking into account the capitalization, the structure of portfolios was not as stable as in the case of the criterion of the number of companies. There have been significant fluctuations during the analyzed period and they occurred in all portfolios (e.g. the portfolio B/L constituted 49,55% of whole capitalization in June 1998, while in June 2003 – almost 95%). Two portfolios consisting of small companies constituted together on average only 4,09% of whole capitalization while the portfolio B/L constituted on average almost ¾ of whole capitalization.

Table 1: Structure of portfolios taking into account the number of companies at the moment of classification

The moment of classification. The end of month	The number of companies in the portfolio					The share of companies in portfolio in total number of companies (%)			
	S / L	S / H	B / L	B / H	Total	S / L	S / H	B / L	B / H
1994.06	6	6	6	7	25	24,00	24,00	24,00	28,00
1995.06	9	17	17	9	52	17,31	32,69	32,69	17,31
1996.06	14	23	23	14	74	18,92	31,08	31,08	18,92
1997.06	28	32	32	28	120	23,33	26,67	26,67	23,33
1998.06	34	54	54	35	177	19,21	30,51	30,51	19,77
1999.06	31	71	71	31	204	15,20	34,80	34,80	15,20
2000.06	32	70	70	33	205	15,61	34,15	34,15	16,10
2001.06	31	77	77	32	217	14,29	35,48	35,48	14,75
2002.06	27	71	71	27	196	13,78	36,22	36,22	13,78
2003.06	27	64	64	28	183	14,75	34,97	34,97	15,30
2004.06	32	58	58	33	181	17,68	32,04	32,04	18,23
2005.06	38	71	71	38	218	17,43	32,57	32,57	17,43
2006.06	50	65	65	50	230	21,74	28,26	28,26	21,74
2007.06	57	78	78	57	270	21,11	28,89	28,89	21,11
Sum	416	757	757	422	2 352	–	–	–	–
Average	29,71	54,07	54,07	30,14	168,00	17,69	32,19	32,19	17,94

Source: Calculations by Jerzy Kot

Table 2: Structure of portfolios taking into account capitalization of companies at the moment of classification

The moment of classification. The end of month	Total capitalization (in billions PLN)					The share of the portfolio capitalization in total capitalization (%)			
	S / L	S / H	B / L	B / H	Total	S / L	S / H	B / L	B / H
1994.06	0,39	0,26	3,70	1,65	6,00	6,57	4,26	61,67	27,50
1995.06	0,34	0,40	3,48	2,24	6,46	5,25	6,17	53,92	34,66
1996.06	0,69	1,04	9,13	6,57	17,43	3,94	5,99	52,39	37,68
1997.06	1,60	1,37	17,36	5,10	25,43	6,28	5,40	68,26	20,05
1998.06	1,49	1,60	19,38	16,64	39,11	3,81	4,10	49,55	42,55
1999.06	1,31	1,54	49,72	9,75	62,32	2,10	2,47	79,79	15,65
2000.06	1,07	2,13	116,93	6,26	126,40	0,85	1,69	92,51	4,96
2001.06	1,06	1,55	91,35	5,96	99,92	1,06	1,55	91,43	5,97
2002.06	0,63	1,18	97,04	9,61	108,46	0,58	1,09	89,48	8,86
2003.06	0,48	1,08	105,78	4,12	111,45	0,43	0,97	94,91	3,69
2004.06	1,91	2,25	136,80	14,88	155,84	1,23	1,44	87,78	9,55
2005.06	2,42	2,88	106,02	76,60	187,92	1,29	1,53	56,42	40,76
2006.06	5,91	6,70	239,15	61,56	313,32	1,89	2,14	76,33	19,65

2007.06	14,60	16,25	325,13	196,47	552,45	2,64	2,94	58,85	35,56
Sum	33,90	40,22	1 320,97	417,40	1 812,49	–	–	–	–
Average	2,42	2,87	94,36	29,81	129,46	1,87	2,22	72,88	23,03

Source: Calculations by Jerzy Kot

Estimation results

The monthly average excess returns for all created portfolios were positive during the 1994-2008 period. The portfolio S/L, i.e. the portfolio of small companies which were well valued by the market achieved the highest return, while the return on the portfolio of small companies badly-valued by the market at the moment of classification, was only a little lower. The return on the portfolio of the biggest companies which were well valued by the market at the moment of classification was by far the lowest.

Table 3: Average monthly returns on portfolios for the 1994-2008 period (%)

Portfolio	Average returns	
	non excess	excess
S/L	2,60	1,51
S/H	2,56	1,46
B/L	1,19	0,09
B/H	2,24	1,15
WIG	1,39	0,30

Source: Calculations by Jerzy Kot

All the variables used in the models were stationary which has been documented by the DF test. Nevertheless, the ADF test with the phase-lag of order 12 was applied in order to check whether the January Effect had disturbed the stationarity of the variables. The ADF test with the phase-lag of order 12 also confirmed the stationarity of all variables. The results of tests for the stationarity of variables justify the application of the Generalized Least Squares Method in order to estimate the three-factor models (Charemza & Deadman, 1992).

Table 4: The results of tests for the stationarity of variables in the Fama-French three-factor models

Variable	Estimated value of coefficient δ	
	DF test	ADF test with12 lags
S/L	-0,83***	-0,36*
S/H	-0,88***	-0,33*
B/L	-1,045***	-0,84**
B/H	-1,02***	-0,58*
WIG	-1,05***	-0,64*
SMB	-0,76**	-0,41*
HML	-1,02***	-1,63***

Note:
1. (***) – significance level 0,001, (**) – significance level 0,01, (*) – significance level 0,05
2. All the tests were applied for DF and ADF models without drift and without trend

Source: Calculations by author

In the period in question, there was a strong positive correlation between the returns on all four portfolios and the return on the WIG. The correlation coefficient for the portfolio of big companies highly valued by the market (B/L) was very high (0,97). The returns on small companies were slightly less correlated with the return on the WIG. Nevertheless, in all the above cases the significance level of the results was at least 0,001, which means that the situation on the market has a considerable influence on the returns[6].

The monthly excess returns on the portfolios of small companies are positively correlated with the variable SMB, while the monthly excess returns on the portfolios of big companies are negatively correlated with the variable SMB. The returns on the portfolios with the high book equity to the market equity ratio (portfolios S/H and B/H) were positively correlated with the variable SMB while the returns on the portfolios

[6] When the companies were grouped into six portfolios there was also a strong dependence in the case of portfolio B/L - the value of correlation coefficient was 0,96 (Kowerski, 2008).

where this quotient was low (S/L and B/L) – were negatively correlated with this variable. All results were statistically significant and for the portfolio B/H the significance level was 0,05, for the portfolio S/L – 0,001, and for the remaining two portfolios – 0,01. If the negative correlation coefficients between the variable HML and the returns on the portfolios B/L and S/L are statistically significant, it means that investing in the companies which are highly valued by the market is risk-free. However, investors should accept the lower returns as the price they have to pay for the feeling of safety associated with investing in such companies. By analogy, investing in the portfolios S/H and B/H brings higher returns which is the reward for accepting the higher risk.

The correlation coefficients between the return on the WIG and the variables SMB and HML assumed a negative and statistically insignificant value (level 0,05), while the correlation coefficient between the variables SMB and HML (-0,24) is significant (level 0,01) and relatively high. The correlation coefficient in Davis, Fama and French's (2000) analysis for the 1929-1997 period has been also significant (level 0,05) and reached 0,13.

The models estimated with the Generalized Least Squares Method (heteroscedastisity correction)[7] have the signs of coefficients which are consistent with those of the Fama-French three-factor model and there isn't any autocorrelation of disturbances and ARCH effect. The models are relatively high adjusted. The determination coefficients, depending on the portfolio, fluctuate from 0,863 to 0,942.

In the period in question, the coefficient value with the variable SMB for the portfolio S/L was 0,97 and for the portfolio S/H was 0,91. Since the variable SMB is identified with the risk associated with investing in small companies, it may be expected that increasing this risk by 1% will result in the excess return of around 0,97% for the portfolio S/L and 0,91% for the portfolio S/H (assuming that other explanatory variables do not change). In the same period, the coefficients with the variable HML for the portfolios S/L and S/H were respectively: -0,38 and 0,81. As the variable HML is identified with the risk associated with investing in the companies that are undervalued by the market, it may be expected that

[7] Calculations done in GRETL program: http://www.gnu.org.

increasing this risk by 1% will result in a premium of around 0,86% for those who invest in the portfolio S/H (assuming that other explanatory variables do not change). At the same time, those who invest in the portfolio S/L (the portfolio of small companies highly valued by the market) will have to accept the reduction in returns by 0,38% which may be considered as "a fee for peace and quiet" paid by those who invest in the portfolio of companies which are highly valued by the market. As far as the models of big companies are concerned, the results consistent with the theory were achieved for the model B/L. Both coefficients (with the variables SMB and HML) were negative values (respectively : -0,09 and -0,19) which is justifiable since investing in the portfolio of big companies which are highly valued by the market is free of risk does not exist here (small size and low value) and should not bring an additional premium. The negative values of coefficients with the variables SMB and HML (both are statistically significant) are the result of safety costs which have to be taken into account by those who invest in the portfolio B/L. In other words, those who invest in the low-risk stocks have to accept low returns.
The coefficient value estimated for the model B/H with the variable HML means that if the risk associated with investing in the undervalued companies increases by 1%, the excess return on the portfolio should increase by 0,51%. The negative value of coefficient, though statistically insignificant, with the variable SMB indicates that an investor has to accept loosing a part of his return which is associated with investing in big companies.
Moreover, all the constant coefficients are insignificant which is consistent with the theoretical assumptions. It means that if the investor decides to take no risk: variables WIG, SMB and HML equal zero, the excess return will be zero (statistically insignificant) – the investor who does not take the risks should not expect to receive an additional return.

Table 5: Estimation results for the three-factor models of returns for the period from July 1994 to June 2008. Heteroscedastisity correction

Specification	S/L	S/H	B/L	B/H
Constant	0,38	-0,02	-0,02	0,38

Specification		S/L	S/H	B/L	B/H
Coefficients with variables	WIG	0,91***	1,00***	1,00***	0,91***
	SMB	0,98***	0,91***	-0,09**	-0,02
	HML	-0,38***	0,81***	-0,19***	0,62***
Determination coefficient R^2		0,920	0,942	0,930	0,863
Adjusted determination coefficient Adj. R^2		0,918	0,941	0,928	0,861
F satatistic		628,7***	887,6***	721,9***	345,4***
First order autocorellation coefficient		-0,0674	0,0098	0,0098	-0,0674
Durbin-Watson Statistic (d or d')		1,866	1,932	1,932	1,866
First order ARCH test The null hypothesis: no ARCH effect at 1 Test statistics: LM		0,7932	1,0810	1,0810	0,7932
ARCH test at order 12 The null hypothesis: no ARCH effect at 12 Test statistics: LM		4,8806	3,0278	3,0278	4,8806
Akaike'a information criterion		739,08	762,70	762,70	739,08
Hannana-Quinna information criterion		744,15	767,77	767,77	744,15

Source: Calculations by author

Note:
(***) – significance level 0.001, (**) – significance level 0.01, (*) – significance level 0.05.
Statistic critical value d (d') at significance level 0.05 are d_l= 1.66, d_u= 1.76.

In accordance with the methodology, also the coefficients of models created for the shorter time series were estimated with the Generalized Least Squares Method. All the variables were stationary independently of the length of the time series (the results of D-F tests). In all the estimated models there was no autocorrelation of disturbances.
Generally, the values of coefficients were stable in time. There is almost no change in the value of parameter b which is the measure of the price for the market risk. Independently of the length of the time series, the constant coefficients are statistically insignificant which supports the basic assumption that when taking no risk the investor cannot expect additional profits.

Table 6: Estimation results for the Fama-French three-factor models in different periods

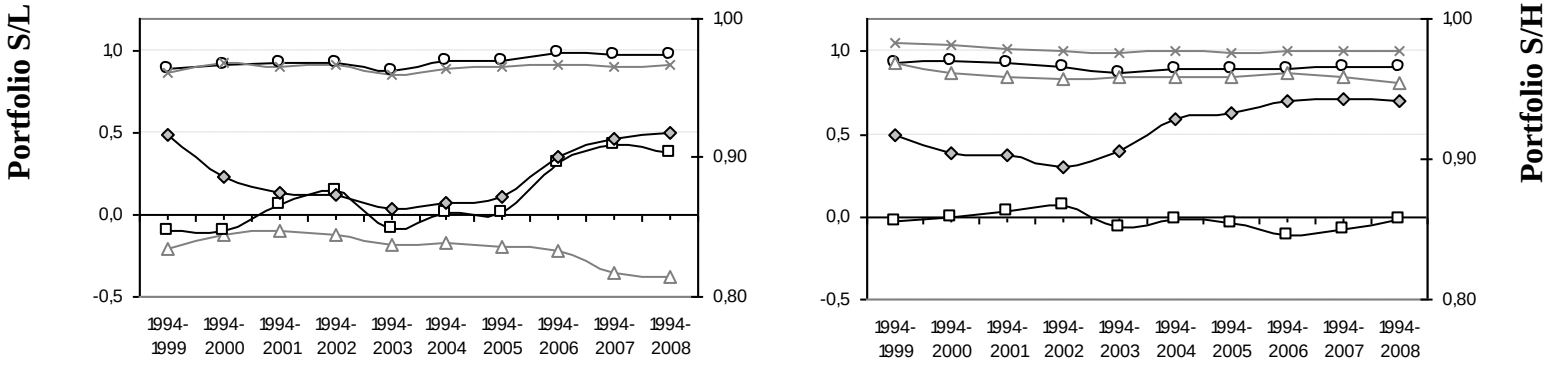
Variable	Coeffi-cient	Estimation period									
		1994-1999	1994-2000	1994-2001	1994-2002	1994-2003	1994-2004	1994-2005	1994-2006	1994-2007	1994-2008
Portfolio S/L											
Constant	**a**	-0,10	-0,10	0,07	0,15	-0,09	0,01	0,02	0,32	0,43	0,38
WIG	**b**	0,87***	0,93***	0,91***	0,91***	0,86***	0,90***	0,90***	0,92***	0,91***	0,91***
SMB	**s**	0,89***	0,92***	0,93***	0,93***	0,88***	0,95***	0,94***	1,00***	0,98***	0,98***
HML	**h**	-0,21	-0,12	-0,09	-0,12	-0,18**	-0,17**	-0,19***	-0,22***	-0,35***	-0,38***
Adj. R^2		0,92	0,89	0,87	0,87	0,86	0,87	0,87	0,90	0,91	0,92
Portfolio S/H											
Constant	**a**	-0,03	0,00	0,04	0,07	-0,06	-0,01	-0,03	-0,11	-0,08	-0,02
WIG	**b**	1,05***	1,05***	1,02***	1,00***	1,00***	1,00***	1,00***	1,00***	1,00***	1,00***
SMB	**s**	0,94***	0,94***	0,93***	0,91***	0,87***	0,89***	0,90***	0,90***	0,91***	0,91***
HML	**h**	0,93***	0,88***	0,85***	0,83***	0,84***	0,85***	0,85***	0,87***	0,85***	0,81***
Adj. R^2		0,92	0,90	0,90	0,89	0,91	0,93	0,93	0,94	0,94	0,94
Portfolio B/L											
Constant	**a**	-0,03	0,00	0,04	0,07	-0,06	-0,01	-0,03	-0,11	-0,08	-0,02
WIG	**b**	1,05***	1,05***	1,02***	1,00***	1,00***	1,00***	1,00***	1,00***	1,00***	1,00***
SMB	**s**	-0,06	-0,06	-0,07	-0,09*	-0,13***	-0,11***	-0,10***	-0,10***	-0,09***	-0,09***
HML	**h**	-0,07	-0,12	-0,15*	-0,17**	-0,16**	-0,15***	-0,15***	-0,13***	-0,15***	-0,19***
Adj. R^2		0,92	0,91	0,92	0,92	0,93	0,93	0,93	0,93	0,93	0,93

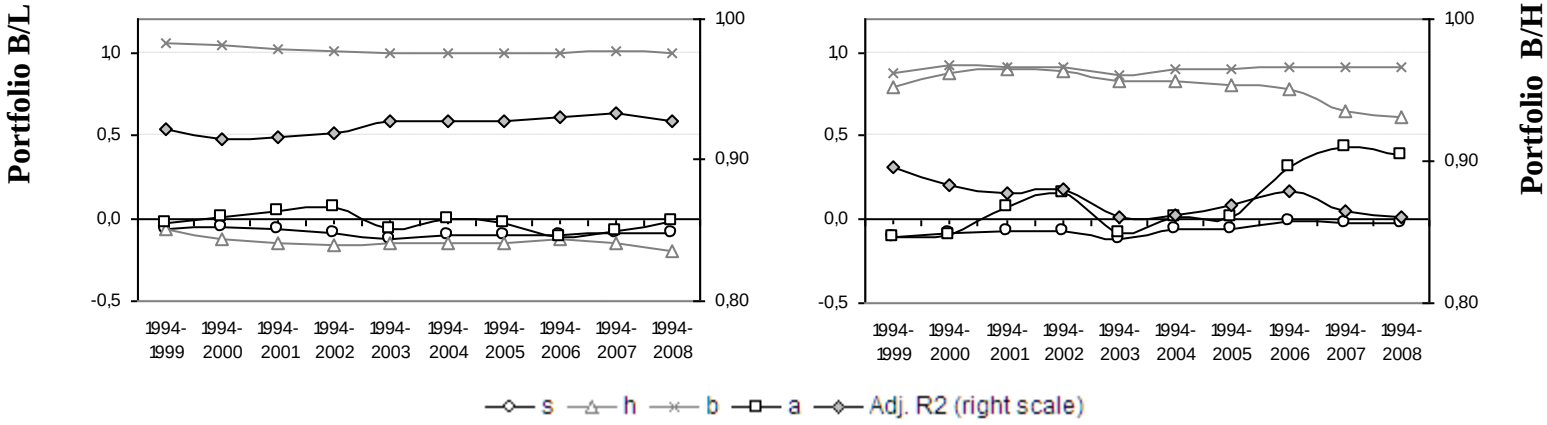
Variable	Coeffi-cient	Estimation period									
		1994-1999	1994-2000	1994-2001	1994-2002	1994-2003	1994-2004	1994-2005	1994-2006	1994-2007	1994-2008
Portfolio B/H											
Constant	**a**	-0,10	-0,10	0,07	0,15	-0,09	0,01	0,02	0,32	0,43	0,38
WIG	**b**	0,87***	0,93***	0,91***	0,91***	0,86***	0,90***	0,90***	0,92***	0,91***	0,91***
SMB	**s**	-0,11	-0,08	-0,07	-0,07	-0,12*	-0,05	-0,06	0,00	-0,02	-0,02
HML	**h**	0,79***	0,88***	0,91***	0,88***	0,82***	0,83***	0,81***	0,78***	0,65***	0,62***
Adj. R^2		0,90	0,88	0,88	0,88	0,86	0,86	0,87	0,88	0,86	0,86

Note: (***) – significance level 0.001, (**) – significance level 0.01, (*) – significance level 0.05

Source: Calculations by author

Figure 1: Changes of parameters in three-factor models depending on the period of model estimation





Source: Calculations by author

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The longer the time series are, the higher is the significance of coefficients which were insignificant in the first years (though the signs are consistent with the hypotheses of the Fama-French three-factor model). It refers to the coefficient h in the models of portfolio S/L and the coefficients s and h in the models B/L. The significant "improvement" results from the lengthening of the time series. As the time series become longer the adjustment of the analyzed models (measured with determination coefficients) improves minimally.

Conclusions

The analysis above, based on the Warsaw Stock Exchange, shows that if the number of listed companies is small, it is advisable to group all the companies into four portfolios in order to estimate the SMB and HML variables instead of six portfolios as suggested by E. Fama and K. French in their three-factor model.

The models based on variables so defined, fully confirm the thesis posed by Fama and French that in addition to the market risk there are two other risk factors which influence the return on investment. These are: the risk associated with investing in small companies and the risk connected with investing in the companies undervalued by the market. The three-factor risk models estimated for the Warsaw Stock Exchange are characterized by high stability.

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