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Managerial Economics 7, 121-129

2010

Ekonomia Menedżerska
2010, nr 7, s. 121–129

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1. Introduction

The cross-sectional differences in asset expected returns have attracted considerable attention in finance literature. Sharpe [17], Lintner [12] and Mossin [13] independently developed a theory, commonly called the capital asset pricing model (CAPM), which states that there is a positive linear relationship between expected stock returns and beta, and beta is a sufficient variable to explain cross sectional stock returns. Over the last two decades, a number of studies have empirically examined the performance of the static (unconditional) version of the CAPM in explaining the cross-section of observed average returns. Although the results of the first tests of the CAPM ([3], [8]) carried out on 1963-1990 data indicated that there is a simple positive relationship between average stock returns and beta coefficient, later studies of Reinganum [14], Lakonishok and Shapiro [11], carried out on later data, did not confirm such a relationship. These studies showed that standard version of the CAPM model does not fully explain the differences in the cross sectional stock returns of various equities. Further research proved that some assets, grouped according to the financial characteristics of analyzed firms, present distinct returns not captured by the beta. For instance, portfolios containing firms with low market value, or low market value relative to book value, turned out to have higher returns than CAPM predicted ([1], [2]).

The failure of the standard version of the CAPM in explaining the differences in the stock returns of shares was the reason for searching for other factors which would better explain the differences in the stock returns. Empirical studies of these differences would allow to confirm that stock returns depend on various ratios characteristics for the companies, e.g. their size, book-to-market equity or

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earnings to share price ratio. The size effect was investigated among others by Banz [1] and Reinganum [14] who found a return premium on some small stocks. The book-to-market effect was studied by Rosenberg et al. [15] and confirmed later by Blume and Stambaugh [4]; where the premium was found in the case of stocks with high ratios.

In view of such empirical evidences, Fama and French ([6], [7]) proposed a multifactor model capable of explaining such anomalies (patterns in average stock returns [7]). The result of their efforts was a multifactor model that introduced two other explanatory variables in addition to he CAPM factor: a premium for the firm size and a premium for the market value relative to the book value. In other words, the Fama-French multifactor model assumed that the excess return of the portfolio over the risk-free rate may be explained by three factors: the excess return of the market portfolio ($R_M - r_f$), the return spread between portfolios with big and small firms (SMB), and the return spread between firms with high and low book-to-market equity ratio (HML).

It is known that in order to carry out empirical verification of the accepted economic model, it is necessary to present an econometric model in which estimated unknown parameters as well as their statistic relevance will confirm or falsify the accepted theoretical solution. One of the most widely used methodologies is the two-pass regression approach known as the Fama-MacBeth procedure, developed by Fama and MacBeth [8] and Black et al. [3]. In this approach, the risk-return relationship is estimated in two stages. At the first stage, beta estimates are obtained from the separate time-series regressions for each asset. Then, these estimates are used in the second-pass cross-sectional regression (CSR). Since the independent variable in the CSR is measured with error, the second-pass estimate is a subject to an errors-in-variables (EIV) problem where Ordinary Least Square (OLS) or General Least Square (GLS) or Weighted Least Square (WLS) estimates are inconsistent. Black et al. [3] derived the sampling distribution of the estimates under the assumption that measurement errors in the betas obtained in the first stage are small enough and can be ignored, while Fama and MacBeth [8] suggested conducting cross-sectional regression for each period and treating the estimates as independent samples of the estimated parameter. Although this method has been initially applied for one-dimension case only, the generalization for multi-dimensional case is automatic. The asymptotic statistical properties of those procedures were established first by Shanken [16] with an assumption that asset returns, conditional on the factors, joined normal distribution with constant variance, and this was later extended by Jagannath and Wang [9], to the case when the asset returns follow a stationary and ergodic process.

The goal of the present paper is to investigate the asset pricing model for the Polish stock market. The empirical work includes the verification of the

Fama–French (FF) model over the sample period of years 2003-2007; where the year 2003 is the year preceding Poland's entrance into the EU, and the following years are the time of Polish membership in the EU. Financial data were obtained from the CEDULA which is an official publication of the Warsaw Stock Exchange (WSW). The analysis was restricted to companies with available returns. All prices were closing prices adjusted for splits and dividends.

The study has the following structure. In Section 2, the methodology for estimating model parameters is presented. The empirical study is discussed in Section 3. The paper ends with concluding remarks.

2. Methodology

The W-factor asset pricing model predicts that there is a linear relationship between the expected excess of portfolios and certain factors $\beta_i^1, \ldots, \beta_i^W$:

$$E(R_t^i) = \gamma_0 + \gamma_1 \beta_i^1 + \gamma_1 \beta_i^2 + \ldots + \gamma_W \beta_i^W, \tag{1}$$

where γ_j, $j = 1, \ldots, W$, are the risk premiums. Asset returns are governed by the following linear relation:

$$R_t^i = \alpha_i + \beta_i^1 f_t^1 + \ldots + \beta_i^W f_t^W + \varepsilon_t^i, \; t = 1, \ldots, T, \; i = 1, \ldots, N, \tag{2}$$

where R_t^i is the excess return on asset i, and $f_t^1, \ldots, f_t^W$ are realizations of the W factors in period t.

The popular Fama–MacBeth methodology runs a CSR of returns $R_t = [R_t^1, \ldots, R_t^N]$ on $\hat{X} = [1_N, \hat{\beta}_{t-1}]$, where the matrix $\hat{\beta}_{t-1}$ is estimated from the regression:

$$R_\tau^i = \alpha_i + \beta_{i,t-1}^1 f_\tau^1 + \ldots + \beta_{i,t-1}^W f_\tau^W + \sigma_\tau^i \tag{3}$$

for $\tau = t - S, t - S + 1, \ldots, t - 1$; $i = 1, \ldots, N$; $t = S + 1, \ldots, T$. As a result, the series of $\hat{\gamma}_{0,t}, \hat{\gamma}_{1,t}, \ldots, \hat{\gamma}_{W,t}$ are obtained. Finally, the estimators $\hat{\gamma}_j$ $(j = 0, \ldots, W)$ are taken as averages of the respective series.

The use of the predictive beta $\hat{\beta}_{t-1}$ in the CSR estimation has some advantages. Firstly, the problem of a spurious cross-sectional relation arising from statistical correlation between returns and estimate market betas can be avoided. Secondly, the independence between the explanatory variable $\hat{\beta}_{t-1}$ and the regression error term in the CSR can be maintained. In recent years, several researchers have recommended GLS over OLS for the cross-sectional regression. It is well known that GLS can be more efficient than OLS. However, both approaches does not take the errors in beta estimators into consideration.

The N-consistent estimator of unknown parameters, obtained from the Maximum Likelihood (MLE) method, was discussed by Kim [10]. He investigated the errors-in-variable problem of estimating Γ for the one-factor case. The multidimensional case was discussed in Chen and Kan [5] draft. This N-consistent estimator omit the error-in-variable problem but is very sensitive on the sample size (with respect to the number of portfolios).

Let $\widehat{\Sigma}_t$ be an $S \times S$ residual covariance matrix, and $\widehat{V}_t$ be a $W \times W$ factor covariance matrix. Then

$$G_t = \begin{bmatrix} 1 & 0 & 0_W^T \\ 0 & 0 & 0_W^T \\ 0_W & 0_W & \widehat{V}_t^{-1} \end{bmatrix} \text{ and } \widehat{A}_t = [R_t, 1_N, \widehat{\beta}_t]^T \widehat{\Sigma}_t^{-1} [R_t, 1_N, \widehat{\beta}_t] \ ,$$

and let $x_t = [x_{0,t}, x_{1,t}, \ldots, x_{W+1,t}]^T$ be an eigenvector associated with the largest eigenvalue of $\widehat{A}_t^{-1} G_t$. Then, the estimators $\widehat{\gamma}_{0,t}, \widehat{\gamma}_{1,t}, \ldots, \widehat{\gamma}_{W,t}$ are given by $\widehat{\gamma}_{j,t} = \frac{-x_{j+1,t}}{x_{0,t}}, j = 0, \ldots, W$. The estimators $\widehat{\gamma}_j \ (j = 0, \ldots, W)$ are taken as averages of the respective series.

3. Empirical Analyses

3.1. Data set, factors and portfolios construction

In May 2004 Poland has joint the European Union. The number of stocks had been growing significantly. The range of listed firms raised from 156 in 2002 to 354 in 2007. To avoid possible distortions, this empirical study uses the sample that spans from January 2003 to the end of 2007. Financial data were obtained from the CEDULA which is an official publication of the Warsaw Stock Exchange. All prices are closing prices adjusted for splits and dividends.

The fundamental data, ME (firm size) and BE/ME (book-to-market value) have been taken at the beginning of each month. The monthly returns were defined as $R_{i,t} = \ln\left(\frac{P_{i,t}}{P_{i,t-1}}\right)$ where $P_{i,t}$ is the price of asset i at time t. The risk free rate has been calculated from the fixed-interest rate of 52-weeks government bonds. The methodology was essentially the same as that of Fama and French papers [6] in construction of the three-factor model. Initially, for the construction of the portfolios, all stocks listed in the CEDULA from January 2003 to December 2007 had been considered. The financial companies had been excluded from the sample.

The 6 portfolios used to estimate factors SMB and HML had been constructed after the following steps: 1) the stocks had been ordered by the market value (firm size) and divided by the median in two groups of small (S) and big (B) firms; 2) for each one of these groups the stocks were ordered by the BE/ME ratio and subdivided in three groups of high (H), medium (M) and low (L) BE/ME in accordance with the 30th and 70th percentiles. Six equally weighted portfolios: HB, HS, MB, MS, LB, LS, have been obtained. The SMB factor is the average return of the three portfolios of small companies less the average return of the three portfolios of big companies: SMB = 1/3 (SL + SM + SH) − − 1/3 (BH + BM + BH). The HML factor is the average of the two portfolios of companies with high BE/ME less the return of two portfolios of companies with low BE/ME: HML = 1/2 (SH + BH) − 1/2 (SL + BL). The excess return of WIG portfolio $R_{WIG} - r_f$ is the third factor. Alternatively, the excess return of EW (Equally Weighted) portfolio R_{EW} was taken into account, but the results are not included here. The summary statistics and the factors correlations are presented, respectively, in Table 1 and Table 2.

Table 1

Summary statistics of the factors

	EW	WIG	SMB	HML
Average	0.009	0.015	0.008	0.018
Standard deviation	0.068	0.055	0.040	0.041

Table 2

The correlation between $R_{EW,}$ R_{WIG}, SMB and HML factors

	$R_{EW} - r_f$	$R_{WIG} - r_f$	SMB	HML
$R_{EW} - r_f$	1			
$R_{WIG} - r_f$	0.823 (p =0.000)	1		
SMB – r_f	0.578 (p =0.000)	0.231 (p =0.049)	1	
HML – r_f	0.061 (p =0.631)	0.106 (p= 0.397)	0.216 (p =0.068)	1

Table 1 shows that the average of SMB factor is positive, and the effect of small firms is statistically significant. Similarly, the average of HML factor is significantly positive ($p = 0.001$) which means that portfolios with high BE/ME value gain bigger profits.

Table 2 shows the significant correlation between ($R_{EW} - r_f$) and SMB factors, and between $R_{EW} - r_f$ and $R_{WIG} - r_f$, the latter being obvious. Remaining factors are pairwise uncorrelated. Therefore, the $R_{WIG} - r_f$, SMB, and HML factors are considered in this study.

This work aims at testing the Fama-French pricing model with data under several specifications. Two cases have been considered: equally weighted and cap-weighted portfolios. In both cases, the set of portfolios have been constructed in the following way: firstly, the firms have been increasingly sorted by firm size and divided into four quantiles; then the firms in each quantile have been increasingly sorted by book-to-market value and divided into three groups. So, twelve portfolios have been obtained with small distortion of ME and BE/ME.

3.2. Risk premium

The research based on conditional expected values have been performed. In the first stage of investigation, values of parameters beta have been estimated from the history with time window of length S, where S is the number of month. Next, parameters gamma have been estimated using the methods discussed in the previous section by moving the time window one month forward. This procedure has been repeated till the window reached the end of sample. The expected values of regression parameters has been calculated as an average of all estimated gammas. Significance of the estimated parameters has been tested using *t-test* (significant parameters are bolded in the subsequent tables).

Firstly, the equally weighted portfolios have been considered. The results obtained are presented in Table 3.

The size of the window from which betas are estimated is questionable. To get reliable estimators, the length of the window should be as big as possible. On the other hand, the assumption of constant betas might not be fulfilled if the window is too long. Two year window seems to be the most adequate.

It can be seen from Table 1 that the results depend on the estimation method. The results of the OLS method, presented here for the comparison purposes, are unstable. The results of the remaining methods coincide. The differences between the results are caused by imperfectness of estimation tools. One can see, that constant is insignificant independently of the estimation method. The results show the significant impact of factors constructed based on the fundamental values such as firm size and book-to-market ratio value (BE/ME), whereas the market beta has little or no ability in explaining the variation in stock returns.

Table 3

The risk premium estimation for equally weighted portfolios (lag S = 12, 18, 24)

Method	γ_0	$t(\gamma_0)$	γ_1	$t(\gamma_1)$	γ_2	$t(\gamma_2)$	γ_3	$t(\gamma_3)$
***S* = 12**								
OLS	–0.003	-0.280	0.009	1,134	0.006	1.289	0.007	1.539
GLS	0.014	0.440	0.001	0.014	**0.015**	**4.224**	**0.024**	**2.262**
MLE	–0.092	–1.523	0.012	1.437	**0.010**	**5.064**	**0.018**	**3.015**
***S* = 18**								
OLS	–0.004	–0.328	0.006	1,134	0.006	1.289	**0.011**	**2.353**
GLS	–0.008	–1,225	**0.018**	4.027	**0.010**	**9.249**	**0.014**	**3.478**
MLE	–0.024	–1.390	0.037	1.403	**0.011**	**6.320**	**0.019**	**4.429**
***S* = 24**								
OLS	0.004	–0.299	0.006	0.421	0.004	0.758	**0.016**	**2.952**
GLS	–0.003	–1.550	**0.012**	**6.220**	**0.010**	**8.577**	**0.015**	**6.030**
MLE	–0.015	–1.254	0.026	1.306	**0.010**	**7.413**	**0.017**	**5.551**

Next, the cap-weighted portfolios have been considered. The results obtained are presented in Table 4. Results confirm the insignificance of the constant and great influence of the SMB and HML factors.

Table 4

The risk premium estimation for cap-weighted portfolios (lag S = 18, 24, 36)

Method	γ_0	$t(\gamma_0)$	γ_1	$t(\gamma_1)$	γ_2	$t(\gamma_2)$	γ_3	$t(\gamma_3)$
***S* = 12**								
OLS	0.010	0.969	0.002	0.224	**0.020**	**2.519**	**0.010**	**1.879**
GLS	0.072	0.280	–0.071	–0.247	**0.028**	**1.943**	**0.020**	**1.978**
MLE	0.066	0.522	0.085	1.102	**0.033**	**8.033**	**0.028**	**2.351**
***S* = 18**								
OLS	0.006	0.524	0.005	0.421	**0.012**	**2.069**	**0.011**	**2.249**
GLS	0.010	1.327	**0.025**	**7.109**	**0.017**	**8.092**	**0.008**	**4.368**
MLE	0.016	0.062	–0.004	0.753	**0.031**	**10.048**	**0.020**	**3.094**
***S* = 24**								
OLS	0.002	0.0114	0.009	0.623	**0.012**	**1.624**	**0.017**	**3.210**
GLS	0.000	0.286	**0.014**	**8.636**	**0.016**	**13.947**	**0.010**	**10.520**
MLE	0.003	0.261	0.015	1.370	**0.029**	**11.138**	**0.020**	**3.708**

4. Conclusions

The research presented in this paper has been conducted for the Polish stock market in the period of years 2003–2007 which was the time of market rise. Several methods for risk premium estimation have been presented. All the methods have shown the significant impact of SMB and HML factors. The effect of small and medium firms and the effect of firms with high BE/ME value can be noticed. The market factor seems to have little or no ability in explaining the variations in stock returns. Moreover, the constant turned out to be insignificant. Summarizing, the results found in the research tend to support the Fama and French Three-Factor model to explain future returns in the Polish market in the period considered. However, because of the short period which have been studied, the results should be carefully considered. However, it should be taken into account that provided results are based relatively short period of study.

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