ARGUMENTA OECONOMICA
No 2 (49) 2022
ISSN 1233-5835; e-ISSN 2720-5088

Bálint Zsolt Nagy, Tünde Dezméri***

A SIX-FACTOR EXTENSION OF THE FAMA-FRENCH ASSET PRICING MODEL – THE CASE OF THE POLISH STOCK MARKET

Multifactor asset pricing models evolved at an accelerated pace in the past few years after the publication of the Fama and French five-factor model. Despite the results from developed markets which arguably make the sixth momentum factor redundant, the authors showed in this study that in an emerging market, e.g. the Warsaw Stock Exchange, the momentum factor (persistence of returns) is still a major asset pricing factor. The data covers the period 2010-2018 on a monthly granularity, during which the Polish stock market was still considered 'emerging'.

Keywords: multifactor asset pricing, momentum, Warsaw Stock Exchange

JEL Classification: C20, G12
DOI: 10.15611/aoe.2022.2.01

Quote as: Nagy, B. Zs., Dezméri, T. (2022). A six-factor extension of the Fama-French asset pricing model – the case of the Polish stock market. *Argumenta Oeconomica*, 2(49).

1. INTRODUCTION

Asset pricing models, factor-based investing and the question of the precise relationship between risk and expected return, are still major unsettled questions of financial economics even after decades of dominance of the efficient market paradigm and the subsequent criticism especially on the part of behavioural finance. The recent publication of the Fama-French five factor model (Fama and French, 2015) has stirred up renewed interest in these models.

The motivation and aim of this study were twofold: firstly, the authors tried to reconcile the empirically robust five factors of Fama-French with the momentum-factor present in the four-factor model of Carhart (1997), thereby arriving at a six-factor specification; secondly, choosing an emerging market, the Polish stock market as the 'empirical sandbox' for the model validation to allow any emerging market specifics to surface. Although, as discussed in the theoretical and empirical literature

* Babes-Bolyai University, Cluj-Napoca, Romania. ORCID: 0000-0001-9479-2536.
** Wolters Kluwer Financial Services, Cluj-Napoca, Romania. ORCID: 0000-0002-0767-3385.

review, there have been controversies regarding the inclusion of the momentum factor among the five factors globally and also the international results about the validity of the five-factor model, the study contributed empirically by examining the performance of the six factors on an emerging market.

Given that six factors seem much less parsimonious than the original one factor of the CAPM, or the Fama-French three factors, the authors also briefly touched upon the question of whether the inclusion of more factors always improves the general explanatory power of a model.

The structure of the paper is as follows:

Part 1 begins with a theoretical review of the major asset pricing models, with an emphasis on the linear specifications, and continues with a discussion of previous empirical results both on developed and emerging markets.

Part 2 presents the data, their organisation and the details of the process by which the authors arrived at the relevant factor-portfolios and at the values of the return-differences corresponding to those factors. The sample consists of the constituents of the WIG20 and sWIG80 stock market indexes of the Warsaw Stock Exchange (WSE). The authors extracted their monthly average price, total return (including dividend yield), total assets and operating profit between 2010-2018.

Part 3 contains the discussion of endogenous and exogeneous variables, the details of the different econometric specifications, and the presentation of the estimation results. As expected, the addition of the momentum factor has led to significant gains in explanatory power and coefficient significance when compared to the earlier models (based on the same data).

Part 4 presents the final discussion and conclusions, together with the identification of future research questions.

2. LITERATURE REVIEW

2.1. Milestones of asset pricing literature

Asset pricing models and the efficient market hypothesis (Malkiel andFama, 1970) have been in the forefront of financial economics for five decades now. As Fama put it simply in the famous joint hypothesis problem (Fama, 1991), one can never test a stock market's efficiency per se, but only together with testing an equilibrium asset pricing model. The first such popular and successful model was the Capital Asset Pricing Model (CAPM) by Sharpe (1964) and Lintner (1965), the first linear single factor pricing model that only recognised the market risk as a single source of non-diversifiable risk and expected return. Soon, some of the restricting conditions of the original model were lifted and further specifications arose such as the CAPM with taxes (Brennan, 1970), the intertemporal CAPM (ICAPM, Merton, 1973) and the consumption CAPM (Breeden, 1979).

Following the many empirical (Black et al., 1972) and analytical-epistemological Roll's critique (Roll, 1977) challenges, efforts were deployed to rescue the efficient market paradigm by dropping the CAPM altogether and to replace it with multifactor linear models (Arbitrage Pricing Theory – APT, Ross, 1976) that do not employ assumptions regarding investor risk aversion and rationality, but instead derive all important non-diversifiable factors from market data.

Following the discovery of several by now famous stock market anomalies, such as the value effect and the size effect, multifactor pricing models gained further impetus in 1992 with the introduction of the Fama-French three-factor model (Fama and French, 1992, 1995, 1996). The so-called momentum effect based on investor under reaction (Jegadeesh andTitman, 1993) led to the inclusion of a fourth, momentum factor by Carhart in 1997 (Carhart, 1997).

The first frequently cited article which introduced a fifth factor was by Pástor and Stambaugh (2003), who included a market-wide liquidity risk factor among the earlier four factors.

Factor-sensitivities (beta coefficients) were adjusted for systematic liquidity risk later by Acharya and Pedersen (2005) who (in their own words) provided "a unified framework for understanding the various channels through which liquidity risk may affect asset prices"[1].

Recently the Fama-French factors were augmented by two more (profitability and investment), resulting in the Fama-French five-factor model (Fama and French, 2015).

Let us now proceed with a more detailed discussion of the Fama-French three and five factor models, together with a briefer presentation of the Carhart four-factor model.

As is widely known, the Fama-French three factors are market risk, size factor and book-to-market (henceforth B/M) factor, all measured by the return premiums that the market assigns to the stocks exposed to these factors at a certain time in a given market. Fama and French (1992) emphasised that even when the CAPM fails to adequately explain the risk-return relationship, the markets are still efficient, the direct relationship between systematic risk and expected return remains in place, but the earlier mentioned size and value (B/M) anomalies serve as additional sources of, and proxies for, non-diversifiable, systematic risk for which investors demand extra return. Their linear regression takes the form:

$$E\left(R_{it} - R_{Ft}\right) = a_i + b_i\left(R_{Mt} - R_{Ft}\right) + s_i SMB_t + h_i HML_t + e_{it}, \tag{1}$$

where $R_M - R_F$ is the market premium over the risk-free return, *SMB* is the expected return difference between a well-diversified small cap and a well-diversified large cap portfolio, and *HML* is the expected return difference between the well-diversified

[1] Acharya-Pedersen (2005), abstract

highest book-to-market and the well-diversified lowest book-to-market portfolio. In the case of a single asset, every systematic risk factor obviously comes with its own sensitivity coefficient marked by lower-case letters. Evidently, the three-factor model can be regarded as both a generalized CAPM and a specification of an APT model. Many reviews and textbooks emphasize the model's atheoretical approach, i.e. that it does not attempt to explain the systematic factors from any underlying principle, which can be regarded in the authors' point of view as both a limitation and a strength.

The first frequently cited extension of the Fama-French three-factor model came from Carhart in 1997, who introduced the fourth, MOM factor (Monthly Momentum), determined as the expected return difference between the previous period's highest return stocks and lowest return stocks. The justification for including this factor came from the observation of Jegadeesh and Titman (1993) that if the short-term price and return patterns persist, asset returns exhibit 'momentum', therefore one should go long on a momentum portfolio buying the previous six months' 'winner' stocks, and short on the previous six months' 'loser' portfolios. The Carhart MOM model arrived at the following linear specification:

$$E\left(R_{it} - R_{Ft}\right) = a_i + b_i\left(R_{Mt} - R_{Ft}\right) + s_i SMB_t + h_i HML_t + d_i UMD_t + e_{it}, \qquad (2)$$

where among the variables already explained earlier, *UMD*[2] represents the expected return difference between the winner and loser stocks, and b_i the sensitivity of a certain asset towards this risk premium.

The Fama-French five-factor model (Fama and French, 2015) represents an extension of the three-factor model with the inclusion of the so-called profitability and investment factors. The need for further adjustment of asset pricing models came partly from empirical research, such as that of Novy-Marx (2012), who demonstrated that even the original three factors do not have sufficient explanatory power regarding the expected returns. In particular, the high expected returns of heavily investing low profitability companies remained unexplained. Another motivation was given by the need to somehow offer an analytic, theoretical justification of asset pricing factors.

Fama and French included these two new factors arriving at the following specification:

$$E\left(R_{it} - R_{Ft}\right) = a_i + b_i\left(R_{Mt} - R_{Ft}\right) + s_i SMB_t + h_i HML_t + r_i RMW_t + c_i CMA_t + e_{it}, \qquad (3)$$

where the new abbreviations are as follows:

- RMW_t[3] is the expected return difference between the well-diversified highest profitability and the well-diversified lowest profitability portfolio;

[2] Up Minus Down
[3] Robust Minus Weak

- CMA_t[4] is the expected return difference between the well-diversified lowest investment and the well-diversified highest investment portfolio;
- b_i, s_i, h_i, r_i, c_i are the sensitivity coefficients for each factor. If these factors can perfectly explain the variation in returns, then the regression constant (intercept a_i) must not be significantly different from zero.

Another line of research concerns the possibility of deriving the systematic factors from the so-called state variables (consistent with the intertemporal CAPM), which are for the most part represented by shocks to the dividend yield, default spread, one-month Treasury-bill yield, etc. This thread is not explored here, so for a concise review please see Petkova (2006).

Not surprisingly this led to a plethora of asset-pricing factors and, according to some critics (e.g. MacKinlay, 1995), a data-mining bias and overfitting of models. For an overarching taxonomy of asset-pricing models see Harvey et al. (2016), who reported that 315 factors were already identified in the top-ranked financial academic journals.

On a final theoretical note, non-linear asset pricing models which factor in co-skewness and co-kurtosis were also left outside the scope of this paper.

2.2. Review of empirical results about multifactor asset pricing models

This study only focused on some of the most important literature concerning the Fama-French multifactor models, therefore the authors refrained from discussing the APT empirical literature.

Since the original articles by Fama and French (1992, 1995, 1996), the three-factor model has been tested many times, mostly on the cross-section of US companies (e.g. Daniel and Titman, 1997) resulting in a better fit to realised returns than the CAPM. Some of the early testing results concerning global, mainly developed market portfolios were also reviewed.

When it comes to testing the F-F models on local markets, the most important question is whether to use local or global return-differences as risk factor premiums. Griffin (2002) argued that country-specific versions of the Fama and French three-factor model provide better explanatory power than the three-factor model based on global factors. The same applies to risk analysis and cost of capital calculations.

In parallel with the Fama-French tests of their five-factor model, Cakici (2015) performed a set of similar models on developed stock markets confirming the 'classic' three factors, but concluding that there are certain regions (such as Asia-Pacific and Japan) where the additional investment and profitability factors do not add significant explanatory power.

In the original article by Carhart (1997), introducing the four-factor (MOM) model, the empirical testing was carried out on the returns of US mutual funds

[4] Conservative Minus Aggressive

between January 1962 and December 1993. The model was soon successfully tested by Jegadeesh and Titman (2001), and Liew and Vassalou (2000), among others.

The first international tests of the momentum effect came from Rouwenhorst (1998). Later, many studies have shown that momentum manifests itself on a wide range of markets and instruments such as:

- major country-level stock exchange indices, Asness (1997);
- commodity markets, Erb and Harvey (2006);
- currency markets, Okunev and White (2003);
- across several asset classes, Asness et al. (2013).

More recently, Barroso and Santa-Clara (2015) argued that although momentum-based strategies did suffer a lot during the great recession of the 2000s, they still generated a risk-adjusted performance (measured by the Sharpe ratio) of 0.53 compared to values between 0.2 and 0.4 for strategies based on the other F-F factors on a sample spanning from 1927 to 2011.

Asness et al. (2013) gave strong motivation to include momentum among the relevant factors of any asset pricing model. They found compelling evidence for the value and momentum effect on several different regions and several different asset classes (including currency and bond markets), and examined the reasons behind the negative correlation between value and momentum.

Concerning the five-factor model, Fama-French's original empirical validation (Fama and French, 2015) was on the stock return data from the New York Stock Exchange (NYSE), the American Exchange (Amex), and the NASDAQ between July 1963 and December 2013, giving a set of monthly returns for 606 months. The authors used as proxy for the market portfolio the value-weighted portfolio of all stocks in the sample (all listed stocks on the three exchanges for which there was enough data on Size and B/M ratio), and the one-month US treasury rate as a proxy for the risk-free return. They combined and sorted the highest quantile stocks in terms of the different risk factors (forming the highest B/M-Inv, B/M-Inv-Op[5] etc. portfolios and their lowest counterparts). Next, they determined the factor premiums as average return differences between these highest and lowest quantile portfolios. Then they ran linear regressions separately for each factor-combination. The comparison between the regression results was achieved with the help of the GRS test by Gibbons, Ross and Shanken (1989), and of two further measures obtained from the regression intercept (alpha) and the squared deviation of expected return.

The GRS statistic and its associated p-values rejected all factor combinations, i.e. the regression intercepts were significantly different from zero, meaning that there were still significant parts of the expected returns not explained by any of the factor combinations. However, as the authors pointed out, the main interest was the relative performance of these factor combination models. The four- and five-factor

[5] Operating profit factor.

combinations showed superior performance in terms of the GRS statistics and alphas. Furthermore, the best fit was achieved on the 32 size-B/M-Inv sorted portfolios.

Overall, Fama and French (2015) convincingly argued for the outperformance of the three-factor model by the five-factor model at least in the US market, although several reservations should be considered, such as that the HML factor becomes redundant after the addition of the profitability and investment factors. The authors circumvented this by transforming the HML to an HMLO (orthogonal) factor, which only contains the portion of HML-return not explained (in other words orthogonal) by the other factors. Another aspect is the outlier behaviour of small-cap portfolios with negative exposure to *RMW* and *CMA*.

Fama and French (2016) argued that the momentum factor has little effect on model performance if added to their five factors, because portfolio returns sorted on momentum when regressed against the five factors, lead to very disperse regression intercepts. Therefore, although there is a gain in model performance, once again the large momentum returns among small stocks remain unexplained.

Fama and French (2016) also attempted to separate "anomalous variables" from "systematic factors". They argued that the list of anomalies shrinks after correcting for the five factors, on the one hand because the magnitude and statistical significance of the anomalous returns diminish, and on the other, because the returns generated by the anomalies have similar five-factor exposures.

In a recent article, International Tests of a Five-Factor Asset Pricing Model (Fama and French, 2017), the authors tested the above described five factors on out-of-sample regional data covering North-America, Europe, Japan and the Asia-Pacific for the period 1990-2015 (monthly returns). As previously, the comparison of the explanatory power of the different regressions was conducted with the aid of the GRS test combined with the measures derived from the alpha intercept. The three and five-factor models are rejected globally, but local variations of the factors do provide explanatory power, e.g. the relationship between B/M and returns is especially strong on the Japanese market. Interestingly, the higher returns of small-cap, low profitability, heavily investing companies do not fit into the model.

2.3. Previous results for emerging markets including the Polish market

The early studies on emerging markets came generally from the authors that had examined the developed markets previously: Fama and French (1998), Rouwenhorst (1998) and Griffin (2002). These show a pervasive 'value' and 'momentum' pattern: value stocks more exposed to the BM ratio factor generate higher average returns than growth stocks with low BM, and also there is a multi-year momentum in stock returns.

Later studies, such as Cakici et al. (2016), examine the value and momentum effects in three emerging regions (Asia, Eastern Europe, and Latin America), concluding that the value effect is present everywhere, but momentum is not present in Eastern Europe.

Lin (2017) used an extensive sample over a period from 1997 to 2015, finding that the five-factor model consistently outperforms the three-factor model in the Chinese equity market. In contrast to the findings in Fama and French (2015), both value and profitability factors are important, while the investment factor is seemingly redundant for describing average returns in the sample.

For the most part, the emerging market literature confirms the direct relationship between B/M and expected return, and the inverse relationship between capitalisation (size) and expected return (Fama and French, 1998; Barry et al., 2002). Turning to the Central and Eastern European countries, the authors studied the following literature sources.

Foye et al. (2013) examined the stock markets of new members of the European Union (the Visegrad countries, the Baltic states and Slovenia) using the three-factor F-F model on data between June 2005 and July 2012 (weekly returns on approximately 150 stocks, the majority from the Warsaw Stock Exchange). Their results reveal the poor performance of the size factor in the emerging markets. Therefore, they proposed to replace the market value of equity by net income/operating cash flows a proxy for earnings management, and argued that the respecified model has a significantly greater explanatory power.

Perhaps the most comprehensive multifactor asset pricing study on emerging markets (in this case, Central Europe plus Russia and Turkey, components of the MSCI Emerging Europe index) to this date was by Zaremba and Czapkiewicz (2017), which compared the performance of the CAPM, the FF3, Carhart4 and FF5 models, arguing for the superiority of the latter. The study also demonstrated that augmenting the model for any of the 100 further pricing anomalies does not lead to better explanatory power.

As with any emerging market research, multifactor models are not yet commonly employed in Poland, for the usual reasons: the lack of necessary, high-quality data and idiosyncrasies in local risk factors. However, it is possible to list some of the previous efforts in this area:

- the B/M effect, or the value effect, was confirmed by Zaremba and Konieczka (2014),
- the size premium was also confirmed by Welc (2012) and Zaremba and Konieczka (2015),
- the momentum effect was documented in Czapkiewicz and Wójtowicz (2014),
- some literature attempted to apply the original Fama-French model (Urbański, 2012; Waszczuk, 2013). More recently Zaremba and Konieczka (2017) applied the classic Fama-French three-factor and Carhart models based on local and international factors in the Polish market. These studies are somewhat contradictory in that they tend to confirm the value and size premiums, but the momentum effect remains ambiguous.

3. DATA AND METHODOLOGY

3.1. Construction of systematic risk factors and left-hand size portfolios

The authors concentrated on the study of the Polish capital market, because it is one of the most liquid stock markets in Central Europe, and as highlighted in the previous literature review there are already numerous studies about multifactor models in this market. Moreover, it was recently upgraded (namely, the decision in September 2017, effective from September 2018)[6] from "developed stock market" (from "emergent"), therefore it is likely that it will receive increased attention from academia and researchers to see how this process of quick maturing could affect liquidity, informational efficiency and the validity of multifactor asset pricing etc.

The authors included the component stocks of the WIG20 and the sWIG80 indexes, computing their daily logarithmic returns between 28 January 2010 to 28 January 2018 (a total of 97 months, the last month included) a period in which the exchange was still considered "emerging". The study did not include components of the index mWIG40 as the authors felt that the study already covered blue chip stocks and small stocks, and both previously mentioned indexes also contain middle-cap stocks. The construction of systematic risk-factors was based on monthly stock market return and accounting data, sourced from Thomson Reuters database. From the total amount of 100 stocks, 90 were considered during the analysis, since they contained the required data over the whole estimation period. Over the length of the study, the portfolios were not adjusted to reflect annual revisions of the indexes.

The empirical methodology consists in the following steps:

- computation of the risk premiums of the different factors (the right-hand side (RHS) of the models;
- computation of the returns of the portfolios formed from index constituents sorted by the different risk factors (left-hand side (LHS) of the models);
- running linear regressions with the generalised method of moments (GMM);
- testing the regressions with the GRS test of Gibbons, Ross, and Shanken (1989).

In the first step, the computation of risk factor premiums, the authors performed the calculation of return differences of the different factors by subtracting from the average return on a portfolio of stocks with the highest value of the corresponding factor the average return on a portfolio of stocks with the lowest value of the corresponding factor. For the sorting of stocks based on these factors, the factors themselves were obtained in the following way:

1. For the market risk premium, the authors calculated the return difference between the WIG20 index and the yield of the three-month Polish treasury bill as a proxy for the local risk-free return.

[6] https://www.ftse.com/products/indices/country-classification

2. For the size premium the capitalisation of each company was obtained in the usual way, by the product of number of shares outstanding and stock price.

3. The third factor was based on the book-to-market ratio of each company.

4. Instead of operating profitability, the study employed the return on equity (annual ROE) indicator as a proxy for profitability, similarly to Cakici (2015) who used return on assets (ROA) for the same purpose.

5. The investment factor was based on the growth rate of a company's total assets of one-year annual growth.

6. Finally, the authors included momentum as the sixth factor calculated as the historical average logarithmic return over the last year.

Following Fama and French (2015), each risk factor then formed the basis of a double-sorting procedure based on size and one of the additional factors. In total, the study obtained 16 double-sorted, equally weighted factor portfolios (sorted by size and then by one of the other five factors, starting with book-to-market ratio) containing 22-23 stocks. Thus, the return differences defining the RHS factors were:

$$
\begin{aligned}
SMB_t &= 1/2\left(R_t^{SH} + R_t^{SL}\right) - 1/2\left(R_t^{BH} + R_t^{BL}\right),\\
HML_t &= 1/2\left(R_t^{SH} + R_t^{BH}\right) - 1/2\left(R_t^{SL} + R_t^{BL}\right),\\
RMW_t &= 1/2\left(R_t^{SR} + R_t^{BR}\right) - 1/2\left(R_t^{SW} + R_t^{BW}\right).\\
CMA_t &= 1/2\left(R_t^{SC} + R_t^{BC}\right) - 1/2\left(R_t^{SA} + R_t^{BA}\right),\\
UMD_t &= 1/2\left(R_t^{SU} + R_t^{BU}\right) - 1/2\left(R_t^{SD} + R_t^{BD}\right).
\end{aligned}
\tag{4}
$$

For instance, the first equation translates into forming the large cap (B) and the small cap (S) portfolios based on the median value of market capitalisation of the constituent stocks. These two portfolios were then sorted again in descending order of the book-to-market ratio of their constituents and grouped into the corresponding medians of "high" and "low" BM ratio.

In these specifications, SH stands for small size, high book-to-market, SM for small size, medium book-to-market, SL for small size, low book-to-market. Similarly, BH and BL stand for big size combined with high and low book-to market ratio. In the subsequent formulas, the grouping of factor portfolios followed the same logic, with the already introduced abbreviations of R (robust), W (weak), C (conservative), A (Aggressive), U (up) and D (down).

Next, these portfolios were rebalanced at the end of each quarter as capitalisation, BM ratio, investment, and profitability, while the previous returns determining the momentum factor were constantly changing.

In the second step, 16 double-sorted portfolios were formed based on similar orderings (sorts) as above (the left-hand side (LHS) portfolios).

Table 1

Descriptive statistics for the risk factors (January 2010 to January 2018)

	RM	SMB	HML	RMW	CMA	MOM
Average return	0.92%	–0.60%	0.13%	–1.95%	–0.99%	1.59%
Standard deviation	8.55%	2.41%	2.46%	5.43%	3.62%	7.92%
t statistics	1.054	–2.439	0.518	–3.519	–2.680	1.967

Source: authors' calculation.

Looking at the summary statistics for risk factors (Table 1), one can see that the average return premiums are quite small (even negative for half of the factors), which could be a consequence of the bearish trend from 2015-2016. Momentum appears to be the factor with the largest premium (1.59%), and its prominence is emphasised by the regression results in the next sub-chapter (2.2). Apart from momentum, the market (RM mean = 0.92%) and value (HML mean = 0.13%) had the expected positive sign, the size effect did not manifest itself (SMB mean = -0.60%), as discussed in the next chapter.

Table 2

Descriptive statistics for the LHS portfolios (January 2010 – January 2018)

Portfolios	BH	BL	SH	SL	BR	BW	LR	LW
Average return	1.16%	0.72%	0.25%	0.44%	0.31%	1.57%	–0.54%	2.09%
Standard deviation	0.040	0.038	0.033	0.053	0.041	0.038	0.040	0.105
t statistics	2.841	1.856	0.742	0.813	0.741	4.048	–1.323	1.950
Portfolios	**BA**	**BC**	**SA**	**SC**	**BU**	**BD**	**SU**	**SD**
Average return	0.69%	1.20%	–0.15%	1.32%	0.51%	1.37%	–0.32%	1.61%
Standard deviation	0.038	0.039	0.039	0.074	0.041	0.037	0.044	0.083
t statistics	1.779	3.015	–0.377	1.748	1.219	3.628	–0.713	1.901

Source: authors' calculation.

Examining the summaries for the stock portfolios (Table 2), one can also see that the smaller capitalisation portfolios did not generally outperform the bigger capitalisation ones (except for SC vs. BC and SD vs. BD). Furthermore, one could not observe the monotonic increase of returns from big capitalization to small capitalisation portfolios, nor the monotonic increase of returns from low B/M stock portfolios to high B/M portfolios.

3.2. Multifactor asset pricing linear regressions

The parameters of the model were estimated by means of the generalised method of moments (GMM). The left-hand side dependent variables are the 16 double-sorted portfolios described in the earlier chapter, and the right-hand side regressors are the five and six systematic risk factors. Overall, the authors obtained a set of 2-16 linear regressions.

Table 3 contains the tests for stationarity and multicollinearity. All the variables were stationary based on the Augmented Dickey-Fuller test. Except for the RMW and CMA factors that were moderately correlated, all the other factors were not correlated.

Table 3

Stationarity and multicollinearity testing results

Dependent variables	Augmented Dickey-Fuller test	VIF test
RM	0.01	1.4945
SMB	0.01	1.1459
HML	0.01	1.3644
RMW	0.0157	5.0416
CMA	0.0106	5.1437
MOM	0.01	2.0075

Source: authors' calculations in R Studio.

The two-step GMM estimation was applied for testing for the over-identifying restrictions in the linear regressions as well as for coping with endogeneity issues (errors in variables, stochasticity of regressors, omitted variables, etc.).

To exclude the presence of endogeneity, the study used as instrumental variables the one-month lagged values of the explanatory variables and the sWIG80 index return.

The results of Hansen's J-test are presented in Table 4 for both the six and five-factor models. Based on the results from Table 4, it was concluded that the used instruments are valid for both models, i.e. uncorrelated with the error term.

Table 4

Six-factor and five-factor GMM regressions J-test

Portfolios	J-test six-factor model	*p*-value	J-test five-factor model	*p*-value
1	2	3	4	5
SH	0.4629	0.4963	2.2505	0.1336
BH	0.2946	0.5873	0.7519	0.3859
SL	0.2946	0.5873	0.7519	0.3859
BL	0.4629	0.4963	2.2505	0.1336

1	2	3	4	5
BR	0.0524	0.8190	1.7927	0.1806
SR	0.0178	0.894	1.1054	0.2931
BW	0.0156	0.9004	0.9885	0.7756
SW	0.1648	0.8979	0.3201	0.3785
BA	0.0676	0.7948	1.4960	0.2213
SA	0.064	0.8003	1.3204	0.2505
BC	0.0314	0.8596	1.1965	0.2740
SC	0.0507	0.8218	1.1511	0.2833
BU	1.7685	0.1836	1.9568	0.1619
SU	0.0169	0.8965	1.1783	0.2778
BD	0.735	0.3913	0.5865	0.4438
SD	0.0056	0.9402	0.1492	0.6993

Note: *, **, *** – significance at 10%, 5% and 1% level

Source: authors' calculations in R Studio.

The study also presents the results of the GRS test for the significance of regression intercepts. In order to compare the ability of the five and six-factor model to describe the abnormal returns, the results of the GRS tests for both models were summarised at the bottom of Tables 5 and 6.

The GRS test is one of the most commonly applied econometric tools to test whether the intercepts of multifactor pricing linear regressions are significantly different from zero. The test statistic is as follows:

$$GRS = \frac{T}{N}\frac{T-N-K}{T-K-1}\frac{\boldsymbol{\alpha}^{\boldsymbol{T}}\boldsymbol{\Sigma}^{-1}\boldsymbol{\alpha}}{1+\boldsymbol{\mu}^{\boldsymbol{T}}\boldsymbol{V}^{-1}\boldsymbol{\mu}}, \quad (5)$$

where N – number of left-hand side portfolios, T – sample size (number of time periods), K – number of factors, **α** – vector of regression intercepts, **Σ** – residual covariance matrix, **V** – sample covariance matrix of the factors.

The GRS statistic follows an F distribution under the null hypothesis of all intercepts being zero with N and T – N – K degrees of freedom.

4. DISCUSSION OF RESULTS

In Table 5, which presents the regression coefficients of the five-factor model, the market risk factor (CAPM risk premium) is only marginally significant (at 10%), and only in about half the regressions (9 out of 16). Moreover, the majority of the portfolios have a narrow beta range between 0.22 and 0.50, hence the classical CAPM does not properly explain the variability of returns.

Table 5

Five-factor GMM regressions $E(R_{it} - RF_t) = a_i + b_i(RM_t - RF_t) + s_i SMB_t + h_i HML_t + r_i RMW_t + c_i CMA_t + e_{it}$ for the sixteen double-sorted portfolios

Portfolios	**Systematic factors**					
	RM	**SMB**	**HML**	**RMW**	**CMA**	**Adjusted R^2**
SH	0.3588*	1.2200	–0.5961	0.2577	0.8167	0.3054
BH	0.4757*	1.2368	–1.0053	0.5645	0.6369	0.3045
SL	0.4757*	2.2368	–2.0053	0.5645	0.6369	0.6077
BL	0.3588*	0.2200	–1.5961*	0.2576	0.8167	0.4926
BR	0.3490	0.0799	–1.5783	0.8767	–0.2685	0.4005
SR	0.3834*	2.1184	–1.4433	0.1049	0.4064	0.4067
BW	0.4533*	1.0886	–1.1797	–0.0822	1.6904	0.3439
SW	0.2284	0.5197	–2.0975	–0.7285	–0.911	0.8581
BA	0.2983	–0.0316	–1.8533*	0.3353	0.7803	0.3908
SA	0.4568*	2.1602	–1.0766	0.0835	1.4391	0.3687
BC	0.4954*	1.1772	–0.922	0.5562	0.6192	0.3718
SC	0.2266	0.5977	–2.1402*	–0.1096	–0.5589	0.8083
BU	0.3315	–0.1296	–2.0282*	0.1191	0.8072	0.3193
SU	0.3387	2.1358	–2.1023	0.5726	1.5946	0.3961
BD	0.5008*	1.3801	–0.7662	0.4932	0.5015	0.3706
SD	0.3121	0.7144	–1.2639	–0.8968	0.9629	0.7585
GRS = 1.3057 (p = 0.2703)						

Note: *, **, *** – significance at 10%, 5% and 1% level

Source: authors' calculations in R Studio.

Overall, in this five-factor specification, the two new factors (CMA, RMW) introduced by Fama and French (2015) appear to be insignificant, contradicting the FF five-factor model (or at least it can be categorically rejected for the Polish market). This is in sharp contrast with previous studies on developed markets. Compared to Fama and French (2016), for the majority of the regressions, market risk, size, investment and profitability factors show similar signs, whereas HML is negatively related to asset returns – which is also a definite departure from the results on developed markets. On corroborating this with the figures from Table 6, the authors concluded that this is in accordance with Czapkiewicz and Wójtowicz (2014), who found that momentum (UMD) is a much more important factor than size and value (HML) in the Polish market, although their analysis is only for four factors. Zaremba and Maydybura (2019) also reported that the CMA factor behaves differently on emerging and frontier markets compared to developed markets.

The size factor (SMB) in Table 6 was in seven cases positive, and in nine cases negative. It was concluded that it is almost equally probable for the factor to have a positive or negative coefficient. If one adds to this the fact that the factor is insignificant in quite a few cases (7), it can be concluded that this factor is inconclusive. This is a further confirmation of the disappearing (or at least weakening) size effect already documented in Fama and French (2012), and in Czapkiewicz and Wójtowicz (2014).

When switching over to the six-factor specification which includes momentum, the momentum becomes the most significant factor (significant at 1% level in 14 out of 16 cases). Interestingly, in parallel with the introduction of the sixth, i.e. momentum factor, all other factors gain in significance compared to the five-factor specification.

Table 6

Six factor GMM regressions: $E(R_{it}–RF_t) = a_i + b_i(RM_t–RF_t) + s_iSMB_t + h_iHML_t + r_iRMW_t + c_iCMA_t + d_iUMD + e_{it}$ for the sixteen double-sorted portfolios

Port-folios	Systematic factors						Adjusted R^2
	RM	SMB	HML	RMW	CMA	UMD	
SH	–4.09E-02***	8.27E-02***	1.21E-00***	1.04E-01***	8.49E-02***	5.66E-01***	0.8549
BH	0.0696	–0.0389	0.6017	0.3110	0.0715	0.5359***	0.9009
SL	0.0696	0.9611*	–0.3983	0.3110	0.0715	0.5359***	0.9441
BL	–4.09E-02***	–9.17E-01***	2.12E-01***	1.04E-01***	8.49E7-02***	5.66E-01***	0.894
BR	–2.74E-02***	–7.12E-01***	–2.83E-02***	7.6E-01***	–7.55E-01***	5.24E-01***	0.9337
SR	1.49E-02***	7.74E-01***	–1.70E-01***	9.09E-02***	6.55E-01***	4.56E-01***	0.9298
BW	0.0585	–0.2551	0.5996	0.3804	1.0381	0.5437**	0.7864
SW	–0.0760	0.2685	–0.8045	–0.7555	–1.1560	0.4385	0.9577
BA	–7.62E-02***	–9.03E-01***	–1.24E-01***	1.445E-01***	1.79E-01***	5.38E-01***	0.9189
SA	7.54E-02***	8.83E-01***	2.57E-01***	–4.90E-01***	8.49E-01***	4.83E-01***	0.9295
BC	0.1018	–0.1157	0.7248	0.2489	0.0421	0.5364***	0.8655
SC	–0.1012	0.1059	–0.6014	–0.1503	–1.0035	0.4825***	0.9702
BU	0.0138	–0.9412**	–0.1014	0.1237	0.533	0.4968***	0.8423
SU	–0.148	0.6991	0.1362	0.5814	0.8307	0.6981**	0.8092
BD	0.0604	0.2144	0.6365	0.0616	–0.0485	0.5334***	0.8144
SD	0.1257	0.3589	–0.6645	–0.9811	–1.0700	0.2339	0.9005
GRS=1.413 (p=0.2204)							

Note: *, **, *** – significance at 10%, 5% and 1% level

Source: authors' calculations in R Studio.

The much bigger adjusted R-squared values of the six-factor model compared to the five-factor values indicate a significant overall performance gain of the six-factor model, however the GRS statistic is slightly bigger indicating that the six-factor portfolios are not necessarily more efficient than the five-factor ones. In both cases the null hypothesis of zero regression intercepts cannot be rejected, indicating that these asset pricing factors explain a great deal of the variation in portfolio returns.

At the same time, regression coefficients are much more significant in the six-factor specification (especially for the UMD momentum factor). In many six-factor regressions, the coefficients of all the factors are highly significant, prompting the authors to conclude that overall, six-factor asset pricing is much more appropriate in the Warsaw market.

CONCLUSIONS

In recent years, multifactor asset pricing has attracted significant attention beginning with the introduction of the Fama-French five-factor model. Most previous studies examined either the classic FF3, FF5 models or Carhart's four-factor model on both developed and emerging markets. In this study, the authors contrasted the FF5 specification with a six-factor model including momentum, on the data from a transitioning market (the WSE, which only very recently evolved from an "emergent" to a "developed" market).

The study's main conclusion is that the inclusion of the sixth factor describing the momentum effect significantly improves the explanatory power and the statistical significance of the coefficients of the multifactor asset pricing model. After the inclusion of UMD into the model, all the pricing factors, including size and profitability started to behave more like in the empirical tests of FF5 for developed markets.

Virtually all factors have mixed-sign loadings, only the momentum effect has constant sign and is the most pronounced effect, indicating that at least in the case of the Polish market, momentum is still the most important risk factor in asset pricing. Further studies are needed to examine whether the new status of a "developed" market will affect in any significant way the pricing of these risk factors, but certainly at least a few years must pass for the critical amount of data to be available.

REFERENCES

Acharya, V.V. and Pedersen, L.H. (2005). Asset pricing with liquidity risk, *Journal of Financial Economics*, 77, 375-410.

Asness, C.S. (1997). The interaction of value and momentum strategies. *Financial Analysts Journal*, 53(2), 29-36.

Asness, C.S., Moskowitz, T.J. and Pedersen, L.H. (2013). Value and momentum everywhere. *The Journal of Finance*, 68(3), 929-985.

Barroso, P. and Santa-Clara, P. (2015). Momentum has its moments. *Journal of Financial Economics*, 116(1), 111-120.

Barry, C.B., Goldreyer, E., Lockwood, L. and Rodriguez, M. (2002). Robustness of size and value effects in emerging equity markets, 1985–2000. *Emerging Markets Review*, 3(1), 1-30.

Black, F., Jensen, M.C. and Scholes, M. (1972). The Capital Asset Pricing Model: Some Empirical Tests, in *Studies in the Theory of Capital Markets.* Michael C. Jensen, ed., New York: Praeger, 79-121.

Breeden, D. (1979), An intertemporal asset pricing model with stochastic consumption and investment opportunities, *Journal of Financial Economics*, 7, 265-296.

Brennan, M.J. (1970). Taxes, market valuation and corporate financial policy. *National Tax Journal*, 23(4), 417-427.

Cakici, N. (2015). The five-factor Fama-French model: International evidence. Available at SSRN: http://dx.doi.org/10.2139/ssrn.2601662

Cakici, N., Tang, Y. and Yan, A. (2016). Do the size, value, and momentum factors drive stock returns in emerging markets? *Journal of International Money and Finance*, 69, 179-204.

Carhart, M. (1997). On the persistence of mutual fund performance, *Journal of Finance* 52: 57-82.

Czapkiewicz, A. and Wójtowicz, T. (2014). The four-factor asset pricing model on the Polish stock market. *Economic Research-Ekonomska Istraživanja*, 27(1), 771-783.

Daniel, K. and Titman, S. (1997). Evidence on the characteristics of cross-sectional variation in stock returns. *Journal of Finance*, 52(1), 1-33.

Erb, C.B. and Harvey, C.R. (2006). The strategic and tactical value of commodity futures. *Financial Analysts Journal*, 62(2), 69-97.

Fama, E.F. (1991). Efficient capital markets: II. *Journal of Finance*, 46(5), 1575-1617.

Fama, E.F. and French, K.R. (1992). The cross-section of expected stock returns, *Journal of Finance*, 47, 427-465.

Fama, E.F. and French, K.R. (1995). Size and book-to-market factors in earnings and returns, *Journal of Finance*, 50, 131-155.

Fama, E.F. and French, K.R. (1996). Multifactor explanations of asset pricing anomalies, *Journal of Finance*, 51, 55-84.

Fama, E.F. and French, K.R. (1998). Value versus growth: The international evidence. *Journal of Finance*, 53(6), pp.1975-1999.

Fama, E.F. and French, K.R. (2012). Size, value, and momentum in international stock returns, *Journal of Financial Economics*, 105(3), 457-472.

Fama, E.F. and French, K.R. (2015). A Five-Factor Asset Pricing Model, *Journal of Financial Economics*, 166, 1-22.

Fama, E.F. and French, K.R. (2016). Dissecting anomalies with a five-factor model, *The Review of Financial Studies*, 29(1), 69-103.

Fama, E.F. and French, K.R. (2017). International tests of a five-factor asset pricing model. *Journal of Financial Economics*, 123(3), 441-463.

Foye, J., Mramor, D. and Pahor, M. (2013). A respecified Fama-French three-factor model for the new European Union Member States, *Journal of International Financial Management & Accounting*, 24(1), 3-25.

Gibbons, M.R., Ross, S.A. and Shanken, J. (1989). A test of the efficiency of a given portfolio, *Econometrica*, 57: 1121-1152.

Griffin, J.M. (2002). Are the Fama and French factors global or country specific? *The Review of Financial Studies*, 15(3), 783-803.

Harvey, C.R., Liu, Y. and Zhu, H. (2016). … and the cross-section of expected returns, *The Review of Financial Studies*, 29(1), 5-68.

Jegadeesh, N., and Titman, S. (1993). Returns to buying winners and selling losers: implications for stock market efficiency. *Journal of Finance*, 48, 65-91.

Jegadeesh, N. and Titman, S. (2001). Profitability of momentum strategies: An evaluation of alternative explanations, *Journal of Finance*, 56(2), 699-720.

Liew, J. and Vassalou, M. (2000). Can book-to-market, size and momentum be risk factors that predict economic growth? *Journal of Financial Economics*, 57(2), 221-245.

Lin, Q. (2017). Noisy prices and the Fama–French five-factor asset pricing model in China, *Emerging Markets Review*, 31, 141-163.

Lintner, J. (1965). Security prices, risk, and maximal gains from diversification, *Journal of Finance*, 20(4), 587-615.

MacKinlay, A.C. (1995). Multifactor models do not explain deviations from the CAPM, *Journal of Financial Economics*, 38(1), 3-28.

Malkiel, B.G. and Fama, E.F. (1970). Efficient capital markets: A review of theory and empirical work. *Journal of Finance*, 25(2), 383-417.

Merton, R.C. (1973). An intertemporal capital asset pricing model, *Econometrica*, 41, 867-887.

Novy-Marx, R. (2012). Is momentum really momentum? *Journal of Financial Economics*, 103(3), 429-453.

Okunev, J. and White, D. (2003). Do momentum-based strategies still work in foreign currency markets? *Journal of Financial and Quantitative Analysis*, 38(2), 425-447.

Pástor, Ľ. and Stambaugh, R.F. (2003). Liquidity risk and expected stock returns. *Journal of Political Economy*, 111(3), 642-685.

Petkova, R. (2006). Do the Fama–French Factors Proxy for Innovations in Predictive Variables? *Journal of Finance*, 61(2), 581-612.

Roll, R. (1977), A critique of the asset pricing theory's tests, Part I: On past and potential testability of the theory, *Journal of Financial Economics*, 4(2), 129-176.

Ross, S. (1976). The arbitrage theory of capital asset pricing. *Journal of Economic Theory*, 13(3), 341-360.

Rouwenhorst, K.G. (1998). International momentum strategies, *Journal of Finance*, 53(1), 267-284.

Sharpe, W.F. (1964). Capital asset prices: a theory of market equilibrium under conditions of risk, *Journal of Finance*, 19, 425-442.

Urbański, S. (2012). Multifactor explanations of returns on the Warsaw Stock Exchange in light of the ICAPM, *Economic Systems*, 36(4), 552-570.

Waszczuk, A. (2013). A risk-based explanation of return patterns – Evidence from the Polish stock market, *Emerging Markets Review*, 15, 186-210.

Welc, J. (2012). Mean-reversion of net profitability among Polish public companies. *Accounting & Taxation*, 3(2), 53-64.

Zaremba, A. and Czapkiewicz, A. (2017). Digesting anomalies in emerging European markets: A comparison of factor pricing models, *Emerging Markets Review*, 31, 1-15.

Zaremba, A. and Konieczka, P. (2014). Factor returns in the Polish equity market. *Procedia-Social and Behavioral Sciences*, 110, 1073-1081.

Zaremba, A. and Konieczka, P. (2015). Are value, size and momentum premiums in CEE emerging markets only illusionary*? Czech Journal of Economics and Finance*, 65(1), 84-104.

Zaremba, A and Konieczka, P. (2017). Size, value, and momentum in Polish equity returns: Local or international factors? *International Journal of Management and Economics*, 53(3), 26-47.

Zaremba, A. and Maydybura, A. (2019). The cross-section of returns in frontier equity markets: Integrated or segmented pricing? *Emerging Markets Review*, 38, 219-238.

Received: May 2019, revised: January 2022