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Which Risk Factors Are Priced in the Polish Equity Market? Evidence from Fama–MacBeth Regressions

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Abstract

Aim: The article examines whether locally constructed risk factors are priced in the cross-section of Polish equity returns.

Methodology: The author used monthly data for 1,318 companies listed on the WSE Main Market and NewConnect from July 2002 to December 2025. Local market, size, value, and momentum factors were tested within the CAPM, Fama–French three-factor, and Carhart four-factor frameworks. The analysis applied time-series regressions, the GRS test, and Fama–MacBeth regressions with Newey-West and Shanken-corrected inference.

Findings: Multifactor models described Polish portfolio returns better than the CAPM, but improved time-series fit did not necessarily imply cross-sectional pricing. The momentum factor showed the strongest unconditional premium, while the Fama–MacBeth regressions provided the clearest evidence that size exposure commanded a positive price of risk in the analysed sample. Value and momentum effects were visible in portfolio returns, but their betas did not always yield statistically significant and economically consistent prices of risk.

Implications: The results indicate that factor returns, model fit, and priced risk premia should be interpreted separately. For practitioners, size, value, and momentum may support portfolio construction, but should not be treated mechanically as priced sources of systematic risk.

Originality/value: The article provides a direct beta-pricing test for the Polish equity market using local factors and a broad sample including both the WSE Main Market and NewConnect.

Keywords: asset pricing, Fama–MacBeth regressions, risk factors, Polish equity market, factor models

1. Introduction

The relationship between risk and expected return is a central question of empirical finance. For developed markets a stable hierarchy of benchmark models has emerged, from the CAPM of Sharpe (1964) and Lintner (1965) through the Fama–French three-factor model (FF3F; Fama and French, 1993) and its extension by Carhart (1997) into the four-factor model (C4F). For Poland, earlier WSE studies showed that multifactor models describe Polish equity returns better than the CAPM, but their conclusions varied across sample periods, portfolio constructions, and the choice of local versus international factors. What remains unclear is whether locally constructed factor exposures, rather than company characteristics or average factor returns, were priced in the cross-section.

The above distinction is important. A factor may have a positive average return, or substantially improve time-series fit, yet fail to deliver a significant lambda when its beta is used as a cross-sectional explanatory variable in the sense of Fama and MacBeth (1973). On the Polish market this distinction has direct interpretive consequences: a strong premium need not indicate a priced source of systematic risk, and a weak lambda need not indicate the absence of an effect.

This article addresses the question using monthly data on 1,318 companies listed on the WSE Main Market and NewConnect from July 2002 to December 2025. Local risk factors for market, size, value, and momentum were constructed following Fama and French (1993) and Carhart (1997), and three models (CAPM, FF3F, and C4F) were evaluated through time-series regressions with the GRS (1989) test and through Fama–MacBeth (1973) cross-sectional regressions with Shanken (1992) corrected inference. Two sets of 4×4 test portfolios (sorted on size and book-to-market, and on size and momentum) served as test assets.

Three findings emerged: (i) among the unconditional premia only momentum was reliably different from zero (1.61%/month, $t = 4.41$), while *MKT*, *SMB*, and *HML* carried positive but statistically insignificant means; (ii) the C4F specification provided the lowest GRS statistics among the three models, but the models were still rejected in the GRS tests; (iii) in the cross-section, the clearest evidence in the analysed sample concerned size exposure, whose price of risk was positive and statistically significant across both test-portfolio sets, while *WML* delivered a statistically significant and economically consistent price of risk only within the size-momentum portfolio set; for *HML*, the regressions either did not provide evidence of a positive price of risk or produced a negative estimate inconsistent with the positive average *HML* return; the market beta provided evidence of meaningful pricing only in one FF3F specification estimated on size-B/M portfolios. Improved model fit, in other words, did not automatically translate into priced systematic risk, a result directly relevant to the characteristics-versus-covariances debate.

The contribution is twofold: a direct beta-pricing assessment of local factors for Poland, complementing the existing focus on model fit and predictive characteristics, and a broad sample combining the WSE Main Market and NewConnect, which exposes the cross-section to the liquidity and microstructure frictions documented by Stereńczak (2021) and the CEE literature (Zaremba & Konieczka, 2015, 2017).

The remainder of the article is organized as follows. Section 2 reviews the literature. Section 3 describes data and methodology. Section 4 reports the results, and Section 5 concludes.

2. Literature Review

2.1. Foundational Findings and Cross-Sectional Pricing Tests

The empirical foundations of the FF3F and C4F models came from documented size, value, and momentum regularities. Banz (1981) found that small companies earn higher average returns than large ones, while Basu (1975) and Fama and French (1992, 1993) linked average returns to valuation ratios and book-to-market equity. Jegadeesh and Titman (1993) documented medium-horizon momentum, later incorporated by Carhart (1997) as a fourth factor. These findings motivated the use of locally constructed *MKT*, *SMB*, *HML*, and *WML* factors in the Polish setting.

The two-step procedure of Fama and MacBeth (1973), first estimating betas in time-series regressions, then running period-by-period cross-sectional regressions of returns on those betas, directly addressed whether factor exposures were priced, and is therefore the natural complement to time--series tests such as the Gibbons, Ross, and Shanken (1989) statistic. As the second-pass betas were estimated rather than observed, cross-sectional inference was exposed to an errors-in-variables problem, for which Shanken (1992) proposed an analytic correction. Reporting Newey-West HAC inference together with Shanken errors-in-variables corrected inference is common in beta-pricing tests.

2.2. Characteristics or Factor Covariances?

The interpretation of size, value, and momentum effects is the subject of a long-standing debate. Daniel and Titman (1997) argued that the cross-section of average returns was explained by company characteristics rather than by covariances with factors, while Davis, Fama, and French (2000) showed that with a longer sample the factor-based interpretation remained strong. The question is therefore not whether to reject factor models outright, but whether the observed premiums reflect compensation for factor covariance or instead arise from characteristics, mispricing, limits to arbitrage, or market frictions. Chordia, Goyal, and Shanken (2015) further emphasised that the results were sensitive to the choice of test assets, idiosyncratic noise, and beta-estimation error. A recent contribution by Gray, Limkriangkrai, and Xu (2024) for the Australian market supported a characteristics-based interpretation. This distinction is directly relevant for Poland: strong value or momentum premiums combined with weak lambdas for *HML* or *WML* should not be read as the absence of an effect, but as evidence that a characteristic matters for returns, even when the corresponding factor exposure is not priced as systematic risk.

2.3. Evidence from Poland and Central and Eastern Europe

Studies on Poland show that classical multifactor models are useful, but their conclusions depend strongly on the sample period, portfolio construction, and market coverage. Czapkiewicz and Skalna (2010, 2011) found that the Fama–French model describes the Polish market better than the CAPM, but that its usefulness varies across market phases, which suggests parameter instability. Mościbrodzka (2014) reached a similar conclusion when examining the stability of Fama–French factors on the WSE, showing that results depend on portfolio type, especially the value/growth profile. Czapiewski (2016) provided a methodological reference by applying the Fama–MacBeth procedure and the GRS test to 4×4 portfolios within the Fama–French five-factor framework. Waszczuk (2013a, 2013b) compared local and global risk factors and discovered that domestic factors were more relevant than foreign specifications for Polish equity returns.

The regional literature, especially Zaremba and Konieczka (2015), highlighted the role of value, size, momentum, liquidity constraints, transaction costs, and microcap stocks in CEE equity markets. Stereńczak (2021) additionally documented that a liquidity premium exists on the WSE and is in part captured by the market, size, and value factors. Taken together, this evidence implies that in a sample that includes both the WSE Main Market and NewConnect, *SMB* may capture not only a pure size premium, but also liquidity, information risk, transaction-cost effects, and microstructure frictions associated with very small companies – a caveat that has bearing on the interpretation of the cross--sectional results below.

The closest reference point is Zaremba et al. (2019), who compared the CAPM, the Fama–French three and five-factor models, and the C4F model for Poland. Their study reported that the C4F model performed best and that value and momentum were particularly relevant for Polish equity returns, a finding that supports the inclusion of *WML* here. Their tests, however, focused on model performance and the predictive role of return-related characteristics rather than on a direct Fama–MacBeth beta-pricing test. The more recent five and six-factor specifications by Nagy and Dezméri (2022) and Gnap (2022) confirmed that a larger number of factors should not be treated as automatically producing a complete pricing model. The research gap this article addresses is therefore a direct Fama–MacBeth beta-pricing test of locally constructed *MKT*, *SMB*, *HML*, and *WML* exposures on a broad Polish sample that included NewConnect.

3. Data and Methodology

3.1. Data

The empirical analysis was based on monthly data for 1,318 unique companies listed on the regulated market of the Warsaw Stock Exchange (WSE) and on the alternative market NewConnect (NC). Including NewConnect broadened the cross-section yet calls for cautious interpretation, since NC companies tended to be smaller, less liquid, and more exposed to microstructure effects than those on the WSE Main Market. To assess whether the main conclusions were driven by the inclusion of NewConnect companies, the analysis was additionally replicated for the WSE Main Market only.

Company characteristics used for portfolio formation came from the monthly statistical bulletins of the WSE, separately for the Main Market and NewConnect. Company-level series, in particular market capitalisation and the price-to-book ratio, were obtained after processing and merging the bulletins across months, and then used to construct the size and book-to-market characteristics. The risk-free rate was proxied by the midpoint between WIBOR 1M and WIBID 1M, with the annualised midpoint converted into a monthly rate using the actual number of calendar days in each month and a 365-day year. Excess returns were obtained by subtracting this monthly risk-free rate from raw stock, portfolio, and WIG index returns. Following Zaremba et al. (2019), monthly stock returns above 500% and below -98% were excluded to limit the influence of likely data errors. The empirical sample started on 31 July 2002, the first month for which the complete factor set (*MKT*, *SMB*, *HML*, and *WML*) was available.

The market factor is defined as the excess return on the WIG index, $MKT_t = R_{WIG,t} - R_{f,t}$. Since the sample included both Main Market and NewConnect stocks, WIG was an imperfect proxy for the full investable universe; it was retained as the baseline being the standard benchmark in Polish applications of the CAPM and Fama-French models. The book-to-market ratio was computed as the inverse of the price-to-book ratio whenever the latter was positive, $B/M_i = 1/(P/B_i)$. Momentum followed the standard $12 - 2$ convention of Jegadeesh and Titman (1993): for each stock and month, momentum was the cumulative simple return from month $t - 12$ to month $t - 2$, skipping month $t - 1$ to limit the influence of short-term reversals,

$$MOM_{i,t} = \prod_{j=t-12}^{t-2} \left(1 + r_{i,j}\right) - 1.$$

3.2. Construction of Risk Factors and Test Portfolios

Local Polish risk factors corresponding to the market, size, value, and momentum effects were constructed following the portfolio-sorting logic of Fama and French (1993) and Carhart (1997). All the factor portfolios were value-weighted, which mitigated the influence of the smallest and least liquid stocks, particularly relevant given the inclusion of NewConnect. Due to the structure of the WSE bulletins, company characteristics were measured using the latest data available as of June each year, rather than lagged fiscal-year accounting data as in the original Fama–French procedure.

The size and value factors were constructed from 2×3 portfolios sorted independently on size (median market capitalisation) and on book-to-market (30th and 70th percentiles), yielding six value-weighted portfolios *SL*, *SM*, *SH*, *BL*, *BM*, *BH* (*S*/*B* for small/big; *L*/*M*/*H* for low/medium/high B/M). The factors were then:

$$SMB_t = 1/3\,(SL_t + SM_t + SH_t) - 1/3\,(BL_t + BM_t + BH_t),$$
$$HML_t = 1/2\,(SH_t + BH_t) - 1/2\,(SL_t + BL_t).$$

Size and book-to-market portfolios are formed annually: companies are classified in June of year t and portfolios are held from July of year t to June of year $t+1$. This timing follows Fama and French (1993) and reduces look-ahead bias.

The momentum factor is constructed analogously from 2×3 portfolios sorted independently on size and momentum, with monthly rebalancing because momentum is a dynamic, return-based characteristic. Classification uses information through the end of month $t-1$ and portfolios are held in month t. The winner-minus-loser factor is

$$WML_t = 1/2\left(R_{S,W,t} + R_{B,W,t}\right) - 1/2\left(R_{S,L,t} + R_{B,L,t}\right),$$

where W and L denote winner and loser portfolios within each size group.

Two sets of test assets were used in the cross-sectional analysis: 4×4 portfolios sorted on size and book-to-market, and 4×4 portfolios sorted on size and momentum. Both sets were value-weighted and evaluated from 31 July 2002 to December 2025.

3.3. Time-Series Regressions and the GRS Test

For each test portfolio, three models were estimated: the CAPM of Sharpe (1964) and Lintner (1965), the FF3F model of Fama and French (1993), and the C4F model of Carhart (1997). The full C4F specification was:

$$R_{p,t} - R_{f,t} = \alpha_p + \beta_{p,MKT}\,MKT_t + \beta_{p,SMB}\,SMB_t + \beta_{p,HML}\,HML_t + \beta_{p,WML}\,WML_t + \varepsilon_{p,t},$$

with the CAPM and FF3F obtained as restricted versions in which the loadings on the omitted factors were set to zero. Inference on individual regression coefficients employed Newey and West (1987) HAC standard errors with a maximum lag length of three months. The Gibbons, Ross, and Shanken (1989) (GRS) test was then used to evaluate the joint null hypothesis that all the portfolio alphas equaled zero, separately for each model and each set of test portfolios. Since the GRS test referred only to time-series fit, it was complemented by Fama–MacBeth cross-sectional regressions.

3.4. Fama–MacBeth Cross-Sectional Regressions

The central asset-pricing test was the two-step Fama and MacBeth (1973) procedure. In the first step, factor betas were estimated for each test portfolio using full-sample time-series regressions, requiring at least 24 monthly observations; rolling betas were not used in order to preserve the full time-series span of second-pass regressions and to avoid additional noise from short-window beta estimates. In the second step, monthly cross-sectional regressions of excess portfolio returns on the estimated betas were run. For the full C4F specification,

$$R_{p,t} - R_{f,t} = \lambda_{0,t} + \lambda_{MKT,t}\,\beta_{p,MKT} + \lambda_{SMB,t}\,\beta_{p,SMB} + \lambda_{HML,t}\,\beta_{p,HML} + \lambda_{WML,t}\,\beta_{p,WML} + \eta_{p,t},$$

where $\lambda_{k,t}$ are monthly prices of risk and $\eta_{p,t}$ is the cross-sectional pricing error. Monthly prices of risk were averaged across cross-sections, $\bar{\lambda}_k = (1/T)\sum_{t=1}^{T}\lambda_{k,t}$, and reported with Newey and West (1987) HAC standard errors, t-statistics, and p-values. As the second-step betas were estimated rather than observed, Shanken (1992) errors-in-variables corrected standard errors, *t*-statistics, and *p*-values were also reported, alongside the average cross-sectional R^2.

The interpretation of the Fama–MacBeth results is conservative: a factor is treated as priced only if its estimated price of risk has an economically meaningful sign, is statistically significant, and is broadly consistent with the average realised return of the corresponding factor portfolio.

4. Results

4.1. Descriptive Statistics of Risk Factors

Table 1 reports descriptive statistics for the four local factors. Only WML had an average monthly return reliably different from zero, while MKT, SMB, and HML had positive but statistically insignificant means. Pairwise correlations were low in absolute terms, suggesting that multicollinearity was unlikely to drive the multivariate results. Figure 1 shows the cumulative factor returns, with WML displaying the clearest upward pattern over the sample.

Table 1. Descriptive statistics of local Polish risk factors

Factor	Mean	Median	Min	Max	Std. Dev.	Skewness	Kurtosis	JB
HML	0.38% (1.09)	0.40%	-15.43%	29.61%	5.00%	0.9405	8.6721	401.68***
MKT	0.59% (1.59)	0.71%	-24.55%	20.43%	5.79%	-0.1803	4.6519	31.53***
SMB	0.40% (0.95)	-0.14%	-12.08%	32.34%	5.66%	1.6014	8.7225	485.97***
WML	1.61%*** (4.41)	1.84%	-23.52%	16.96%	5.11%	-0.5725	6.1577	126.28***

Notes: Numbers in parentheses are t-statistics. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Source: own elaboration.

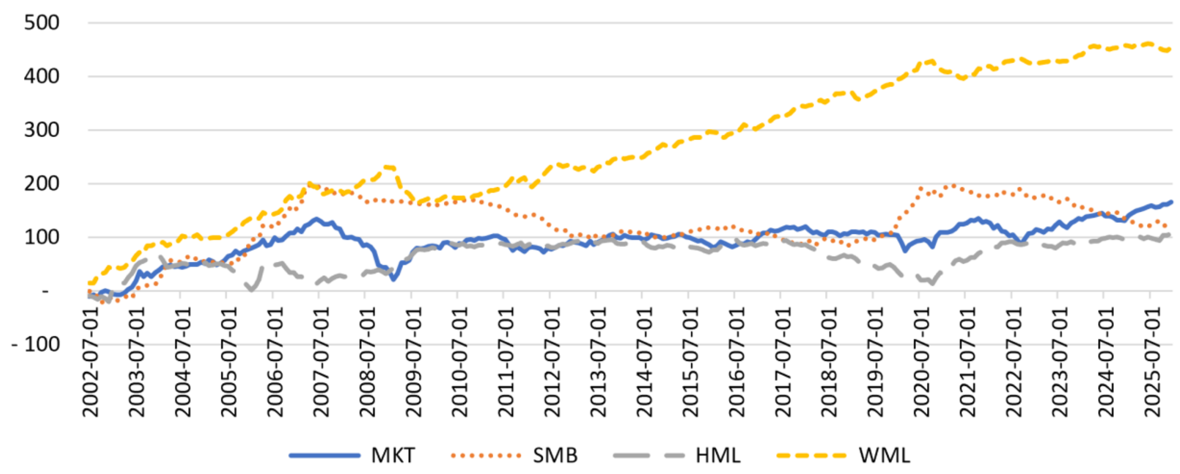

Fig. 1. Cumulative returns of MKT, SMB, HML and WML

Notes: Following Zaremba et al. (2019), cumulative returns were estimated additively for long-short factor portfolios, as cumulative sums of monthly percentage-point returns.

Source: own elaboration.

4.2. Test Portfolios

The mean excess returns, medians, and standard deviations of the two sets of 4×4 test portfolios, reported in Table 2, convey two contrasting messages. For the size–B/M portfolios (Panel A), average excess returns were elevated in the smallest size quartile and statistically significant at the two extreme book-to-market corners: *S1/BM1* at 2.65%/month ($t = 2.40$) and *S1/BM4* at 2.36%/month ($t = 2.60$). Within this smallest size group, returns were not monotone in B/M, with both growth and value corners outperforming the middle. As size increased, mean returns fell sharply and statistical significance became the exception. The overall picture was that of a strong size effect dominating the cross-section, accompanied by a more muted, predominantly small-cap value effect.

The size-momentum portfolios (Panel B) yielded a markedly sharper pattern. Within each of the four size quartiles, average excess returns rose monotonically from past losers (*MOM1*) to past winners (*MOM4*). The spread was most pronounced in the smallest size quartile, where mean returns rose from 2.07% ($t = 3.03$) for *S1/MOM1* to 3.05% ($t = 3.86$) for *S1/MOM4*, and remained economically large even in the largest size quartile, where mean returns increased from –1.06% ($t = -1.76$) for *S4/MOM1* to 1.03% ($t = 2.56$) for *S4/MOM4*. This near-uniform ordering of past winners over past losers across company-size strata that differed markedly in liquidity and microstructure profile provided a particularly demanding ex ante challenge for the CAPM and FF3F and motivated the inclusion of *WML* in the comparative analysis that follows.

Table 2 Descriptive statistics of the 4 × 4 test portfolios

Panel A: Size–book-to-market portfolios				Panel B: Size–momentum portfolios			
Portfolio	**Mean**	**Median**	**Std. Dev.**	**Portfolio**	**Mean**	**Median**	**Std. Dev.**
S1/BM1	2.65%** (2.40)	-1.06%	15.82%	S1/MOM1	2.07%*** (3.03)	0.68%	9.66%
S1/BM2	0.57% (0.75)	-0.72%	10.19%	S1/MOM2	2.15%*** (3.11)	0.75%	9.17%
S1/BM3	1.46%* (1.89)	-0.33%	10.68%	S1/MOM3	2.30%*** (3.52)	0.90%	8.36%
S1/BM4	2.36%*** (2.60)	0.71%	12.97%	S1/MOM4	3.05%*** (3.86)	1.27%	11.00%
S2/BM1	0.91% (1.23)	-0.55%	9.35%	S2/MOM1	-0.57% (-0.92)	-1.37%	8.24%
S2/BM2	0.10% (0.18)	-0.24%	7.03%	S2/MOM2	0.45% (0.83)	-0.11%	6.94%
S2/BM3	1.23%** (2.10)	0.37%	7.74%	S2/MOM3	0.99%* (1.77)	0.10%	6.84%
S2/BM4	0.84% (1.43)	0.29%	7.56%	S2/MOM4	1.78%*** (2.71)	-0.05%	8.78%
S3/BM1	0.21% (0.41)	-0.20%	6.66%	S3/MOM1	-0.49% (-0.81)	-1.03%	8.63%
S3/BM2	0.41% (0.81)	-0.15%	6.61%	S3/MOM2	-0.04% (-0.09)	-0.70%	6.02%
S3/BM3	0.53% (1.19)	0.45%	5.67%	S3/MOM3	0.50% (1.20)	0.29%	5.36%
S3/BM4	0.58% (1.10)	-0.17%	7.79%	S3/MOM4	1.48%*** (2.62)	0.57%	7.21%
S4/BM1	0.28% (0.83)	0.55%	5.77%	S4/MOM1	-1.06%* (-1.76)	-1.47%	8.81%
S4/BM2	0.53% (1.32)	0.39%	6.36%	S4/MOM2	0.21% (0.42)	0.29%	6.93%
S4/BM3	1.20%** (2.09)	0.57%	9.85%	S4/MOM3	0.72%* (1.94)	0.68%	6.33%
S4/BM4	0.60% (1.28)	0.02%	7.95%	S4/MOM4	1.03%** (2.56)	1.31%	6.39%

Notes: Numbers in parentheses are t-statistics. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Source: own elaboration.

4.3. Time-Series Model Fit: CAPM, Fama–French 3F and Carhart 4F

Tables 3 and 4 report time-series regressions of the test portfolios on the CAPM, FF3F, and C4F specifications, with Newey–West HAC standard errors. Inference focused on the alpha estimates, which capture the residual mispricing left unexplained by each model.

For the 4×4 size–B/M portfolios (Table 3), the CAPM left alphas concentrated in the smaller size quartiles, most notably *S1/BM1* and *S1/BM4*, while market betas were uniformly positive and highly significant. Adding *SMB* and *HML* reduced these alphas but did not eliminate them: *S1/BM1* retained $\alpha = 1.84\%$/month ($t = 2.34$), *S1/BM4* $\alpha = 0.76\%$/month ($t = 2.44$), and *S2/BM2* a significant negative alpha of -0.70%/month. *SMB* loadings were large and positive in the smallest size quartile and declined monotonically toward zero as size increased, while *HML* loadings loaded positively on high-B/M corners and negatively on growth corners within the largest size group. Extending the specification to C4F further compressed alphas, although selected pricing errors remained, most notably for S1/BM1 and, marginally, for S2/BM2 and S3/BM1. WML loadings were less systematic than SMB and HML loadings, as expected for portfolios sorted on size and book-to-market rather than on past returns.

Table 3. Time-series regressions for the 4 × 4 size–B/M portfolios: CAPM, FF3F and C4F

Panel A: CAPM		
Portfolio	α	β_{MKT}
S1/BM1	0.0233** (2.21)	0.5376*** (3.64)
S1/BM2	0.0018 (0.26)	0.6584*** (4.89)
S1/BM3	0.0089 (1.45)	0.9508*** (8.05)
S1/BM4	0.0180** (2.52)	0.9493*** (5.74)
S2/BM1	0.0042 (0.70)	0.8251*** (8.26)
S2/BM2	-0.0032 (-0.81)	0.7054*** (12.70)
S2/BM3	0.0079 (1.64)	0.7393*** (8.81)
S2/BM4	0.0034 (0.84)	0.8395*** (10.75)
S3/BM1	-0.0016 (-0.38)	0.6239*** (8.13)
S3/BM2	-0.0004 (-0.12)	0.7652*** (12.46)
S3/BM3	0.0014 (0.44)	0.6625*** (12.56)
S3/BM4	0.0008 (0.22)	0.8869*** (12.74)
S4/BM1	-0.0021 (-1.01)	0.8341*** (23.12)
S4/BM2	-0.0007 (-0.54)	1.0218*** (23.00)
S4/BM3	0.0062 (1.36)	0.9762*** (16.02)
S4/BM4	0.0002 (0.06)	0.9742*** (13.21)

Panel B: FF3F				
Portfolio	α	β_{MKT}	β_{SMB}	β_{HML}
S1/BM1	0.0184** (2.34)	0.8174*** (6.01)	1.4242*** (5.13)	-0.6216 (-1.43)
S1/BM2	-0.0022 (-0.44)	0.7953*** (8.61)	0.8765*** (7.38)	-0.0838 (-0.62)
S1/BM3	0.0046 (1.21)	1.1171*** (10.88)	1.0080*** (7.30)	-0.1701 (-1.54)
S1/BM4	0.0076** (2.44)	1.0702*** (9.85)	1.5715*** (4.71)	0.9058** (2.21)
S2/BM1	0.0008 (0.25)	1.0161*** (12.99)	0.9741*** (9.09)	-0.4220*** (-3.80)
S2/BM2	-0.0070*** (-2.92)	0.7907*** (17.98)	0.7013*** (6.19)	0.1390 (1.35)
S2/BM3	0.0033 (1.13)	0.8214*** (15.81)	0.7897*** (5.39)	0.2746** (2.14)
S2/BM4	-0.0020 (-1.05)	0.8981*** (19.76)	0.8063*** (8.66)	0.4940*** (4.17)
S3/BM1	-0.0039 (-1.34)	0.6993*** (10.43)	0.5035*** (4.75)	-0.0196 (-0.25)
S3/BM2	-0.0034 (-1.41)	0.8274*** (16.55)	0.5292*** (6.58)	0.1226 (1.53)
S3/BM3	-0.0007 (-0.30)	0.7056*** (12.88)	0.3686*** (4.37)	0.0871 (0.93)
S3/BM4	-0.0024 (-1.04)	0.8928*** (14.89)	0.3905*** (3.74)	0.4349*** (3.30)
S4/BM1	-0.0014 (-0.81)	0.8664*** (27.69)	0.0224 (0.54)	-0.2467*** (-4.19)
S4/BM2	-0.0002 (-0.14)	1.0201*** (23.23)	-0.0694*** (-2.84)	-0.0707** (-2.52)
S4/BM3	0.0063 (1.29)	0.9646*** (15.82)	-0.0462 (-0.67)	0.0419 (0.63)
S4/BM4	-0.0010 (-0.31)	0.9061*** (14.93)	-0.0711 (-0.92)	0.4895*** (4.51)

Panel C: C4F					
Portfolio	α	β_{MKT}	β_{SMB}	β_{HML}	β_{WML}
S1/BM1	0.0179** (2.10)	0.8195*** (6.00)	1.4205*** (5.07)	-0.6161 (-1.41)	0.0276 (0.21)
S1/BM2	-0.0022 (-0.41)	0.7952*** (8.51)	0.8768*** (7.54)	-0.0842 (-0.60)	-0.0018 (-0.02)

Panel C: C4F					
Portfolio	α	β_{MKT}	β_{SMB}	β_{HML}	β_{WML}
S1/BM3	0.0015 (0.41)	1.1310*** (10.69)	0.9834*** (7.67)	-0.1331 (-1.22)	0.1840 (1.48)
S1/BM4	0.0035 (0.82)	1.0888*** (8.89)	1.5387*** (5.08)	0.9550** (2.24)	0.2450 (1.40)
S2/BM1	0.0003 (0.09)	1.0182*** (13.62)	0.9705*** (8.92)	-0.4166*** (-3.61)	0.0269 (0.31)
S2/BM2	-0.0055* (-1.92)	0.7840*** (17.67)	0.7132*** (6.76)	0.1211 (1.17)	-0.0890 (-1.38)
S2/BM3	0.0021 (0.72)	0.8268*** (15.24)	0.7802*** (5.47)	0.2889** (2.07)	0.0710 (1.04)
S2/BM4	0.0002 (0.08)	0.8881*** (19.21)	0.8239*** (9.95)	0.4675*** (3.86)	-0.1317** (-2.24)
S3/BM1	-0.0049* (-1.71)	0.7037*** (10.10)	0.4957*** (4.81)	-0.0079 (-0.09)	0.0584 (0.79)
S3/BM2	-0.0015 (-0.57)	0.8189*** (17.06)	0.5442*** (7.18)	0.1000 (1.22)	-0.1125* (-1.73)
S3/BM3	0.0025 (1.02)	0.6913*** (14.91)	0.3938*** (5.37)	0.0493 (0.57)	-0.1883*** (-3.22)
S3/BM4	0.0012 (0.41)	0.8776*** (15.08)	0.4206*** (4.62)	0.3908*** (3.00)	-0.2126*** (-3.21)
S4/BM1	-0.0026 (-1.32)	0.8717*** (28.11)	0.0132 (0.34)	-0.2328*** (-4.14)	0.0690* (1.86)
S4/BM2	0.0006 (0.42)	1.0167*** (25.35)	-0.0633** (-2.51)	-0.0798*** (-2.69)	-0.0454 (-1.12)
S4/BM3	0.0051 (0.90)	0.9700*** (17.70)	-0.0558 (-0.86)	0.0562 (0.78)	0.0715 (0.91)
S4/BM4	-0.0004 (-0.13)	0.9035*** (15.08)	-0.0664 (-0.85)	0.4825*** (4.46)	-0.0352 (-0.45)

Notes: Numbers in parentheses are t-statistics. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Source: own elaboration.

The 4×4 size–momentum portfolios (Table 4) present a less favourable picture. Under the CAPM, the majority of alphas were statistically significant: all four small-company portfolios produced positive alphas exceeding 1.5%/month, and several large-company loser portfolios produced significantly negative alphas, most strikingly *S4/MOM1* at -1.69% ($t = -4.51$). FF3F did not materially help, as alphas remained large and significant for the same group of portfolios, and the winner-loser asymmetry persisted. Only the addition of *WML* compressed this asymmetry. Under C4F, alphas in the smallest size quartile remained positive and significant, particularly *S1/MOM1* at 1.97% ($t = 5.56$) and *S1/MOM2* at 1.66% ($t = 4.51$) but several large-company loser alphas became statistically indistinguishable from zero. The *WML* loadings exhibited a clean monotone pattern, ranging from strongly negative for past losers (e.g. -0.81 for *S4/MOM1*) to strongly positive for past winners (e.g. $+0.41$ for *S4/MOM4*), confirming that the constructed *WML* factor captured the cross-sectional dispersion in momentum exposure of the test portfolios.

Table 4. Time-series regressions for the 4 × 4 size–momentum portfolios: CAPM, FF3F and C4F

Panel A: CAPM		
Portfolio	α	β_{MKT}
S1/MOM1	0.0155*** (2.80)	0.8766*** (9.25)
S1/MOM2	0.0172*** (2.97)	0.7356*** (7.16)
S1/MOM3	0.0185*** (3.48)	0.7488*** (10.40)
S1/MOM4	0.0261*** (3.86)	0.7616*** (6.73)
S2/MOM1	-0.0110** (-2.34)	0.9010*** (11.66)

Panel B: FF3F				
Portfolio	α	β_{MKT}	β_{SMB}	β_{HML}
S1/MOM1	0.0106*** (2.83)	0.9771*** (11.45)	0.8782*** (8.01)	0.2270* (1.65)
S1/MOM2	0.0124*** (3.77)	0.8798*** (11.25)	0.9853*** (7.84)	-0.0111 (-0.07)
S1/MOM3	0.0147*** (3.95)	0.8384*** (15.09)	0.7108*** (6.93)	0.1140 (1.04)
S1/MOM4	0.0217*** (4.28)	0.8938*** (9.14)	0.8933*** (5.14)	-0.0419 (-0.24)
S2/MOM1	-0.0147*** (-4.54)	0.9739*** (13.30)	0.6545*** (5.56)	0.1864 (1.51)

Panel A: CAPM		
Portfolio	α	β_{MKT}
S2/MOM2	-0.0000 (-0.01)	0.7632*** (10.52)
S2/MOM3	0.0055 (1.37)	0.7462*** (8.70)
S2/MOM4	0.0131** (2.51)	0.7969*** (8.26)
S3/MOM1	-0.0105** (-2.39)	0.9488*** (10.87)
S3/MOM2	-0.0046 (-1.40)	0.7144*** (12.79)
S3/MOM3	0.0013 (0.43)	0.6337*** (12.23)
S3/MOM4	0.0102** (2.56)	0.7922*** (9.75)
S4/MOM1	-0.0169*** (-4.51)	1.0997*** (10.88)
S4/MOM2	-0.0037 (-1.53)	0.9753*** (16.81)
S4/MOM3	0.0015 (0.88)	0.9666*** (25.29)
S4/MOM4	0.0051** (2.00)	0.8938*** (13.25)

Panel B: FF3F				
Portfolio	α	β_{MKT}	β_{SMB}	β_{HML}
S2/MOM2	-0.0035 (-1.45)	0.8352*** (13.85)	0.6183*** (5.94)	0.1497 (1.43)
S2/MOM3	0.0018 (0.72)	0.8211*** (14.54)	0.6564*** (7.87)	0.1721** (2.47)
S2/MOM4	0.0081*** (3.04)	0.9424*** (13.84)	1.0154*** (11.53)	0.0149 (0.13)
S3/MOM1	-0.0139*** (-4.01)	0.9730*** (11.08)	0.4752*** (4.57)	0.3787*** (3.07)
S3/MOM2	-0.0069*** (-3.17)	0.7795*** (15.29)	0.4660*** (6.12)	0.0203 (0.23)
S3/MOM3	-0.0009 (-0.42)	0.6793*** (12.90)	0.3938*** (6.20)	0.0976 (1.57)
S3/MOM4	0.0067*** (3.03)	0.8870*** (14.40)	0.6842*** (8.66)	0.0370 (0.54)
S4/MOM1	-0.0175*** (-4.70)	1.0933*** (10.74)	0.0540 (0.60)	0.1221 (1.14)
S4/MOM2	-0.0038 (-1.58)	0.9892*** (17.09)	0.0569 (1.31)	-0.0472 (-0.86)
S4/MOM3	0.0017 (1.01)	0.9696*** (25.03)	-0.0201 (-0.67)	-0.0504 (-1.28)
S4/MOM4	0.0046** (2.09)	0.9273*** (15.39)	0.1585*** (2.81)	-0.0889 (-1.28)

Panel C: C4F					
Portfolio	α	β_{MKT}	β_{SMB}	β_{HML}	β_{WML}
S1/MOM1	0.0197*** (5.56)	0.9360*** (15.22)	0.9507*** (10.84)	0.1181 (1.06)	-0.5424*** (-7.89)
S1/MOM2	0.0166*** (4.51)	0.8610*** (11.30)	1.0183*** (8.74)	-0.0607 (-0.42)	-0.2468*** (-3.13)
S1/MOM3	0.0152*** (3.83)	0.8364*** (14.61)	0.7141*** (7.24)	0.1090 (0.94)	-0.0252 (-0.33)
S1/MOM4	0.0166*** (3.45)	0.9166*** (9.58)	0.8532*** (5.02)	0.0184 (0.10)	0.3002** (2.41)
S2/MOM1	-0.0046 (-1.54)	0.9281*** (19.10)	0.7353*** (8.48)	0.0652 (0.70)	-0.6040*** (-10.94)
S2/MOM2	0.0023 (0.89)	0.8094*** (15.53)	0.6638*** (8.21)	0.0814 (0.92)	-0.3403*** (-5.85)
S2/MOM3	0.0017 (0.68)	0.8215*** (14.52)	0.6556*** (7.91)	0.1733** (2.38)	0.0060 (0.10)
S2/MOM4	0.0007 (0.32)	0.9761*** (16.70)	0.9560*** (10.58)	0.1041 (0.78)	0.4443*** (6.23)
S3/MOM1	-0.0038 (-1.05)	0.9270*** (16.06)	0.5562*** (7.84)	0.2572*** (2.69)	-0.6054*** (-6.98)
S3/MOM2	-0.0031 (-1.37)	0.7620*** (17.69)	0.4967*** (8.15)	-0.0259 (-0.33)	-0.2302*** (-4.59)
S3/MOM3	0.0014 (0.63)	0.6690*** (14.17)	0.4119*** (7.22)	0.0703 (1.20)	-0.1359*** (-2.59)
S3/MOM4	0.0051** (2.36)	0.8943*** (14.64)	0.6713*** (8.66)	0.0563 (0.75)	0.0960 (1.56)
S4/MOM1	-0.0042 (-1.59)	1.0295*** (17.41)	0.1662*** (2.86)	-0.0379 (-0.59)	-0.8080*** (-12.31)
S4/MOM2	-0.0013 (-0.45)	0.9776*** (17.60)	0.0774* (1.75)	-0.0779 (-1.53)	-0.1529** (-2.07)
S4/MOM3	0.0014 (0.69)	0.9713*** (25.21)	-0.0230 (-0.79)	-0.0462 (-1.13)	0.0213 (0.46)
S4/MOM4	-0.0023 (-1.17)	0.9583*** (24.81)	0.1039*** (2.94)	-0.0069 (-0.14)	0.4086*** (8.78)

Notes: Numbers in parentheses are t-statistics. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Source: own elaboration.

4.4. GRS Tests

Table 5 presents the joint Gibbons-Ross-Shanken statistics for each model and each set of test portfolios. For the size-B/M portfolios, all the three models were formally rejected (CAPM at 1.705, FF3F at 1.991, C4F at 1.545), but the C4F specification produced the smallest statistic and the weakest rejection, in line with its marginally better ability to absorb the alphas of the smallest portfolios. For the size-momentum portfolios, the GRS statistics were substantially larger and all three models were rejected decisively at the 1% level. The CAPM (7.493) and FF3F (7.657) statistics were nearly identical, indicating that adding *SMB* and *HML* did not help when test assets were sorted on past returns. The C4F model reduced the statistic substantially, to 5.264, reflecting the contribution of *WML*, but the rejection remained decisive. On the joint test of zero alphas, the C4F specification was the best of the three, yet did not provide a fully successful description of either set of test portfolios.

Table 5. Gibbons–Ross–Shanken tests by model and test-portfolio set

Test portfolios	**CAPM**	**FF3F**	**C4F**
4 × 4 Size–B/M	1.705**	1.991**	1.545*
4 × 4 Size–Momentum	7.493***	7.657***	5.264***

Notes: The table reports GRS test statistics, where *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Source: own elaboration.

4.5. Fama–MacBeth Risk Premia

Table 6 shows the cross-sectional Fama-MacBeth estimates of the prices of risk on the local Polish factors, with both HAC and Shanken-corrected inference, the average cross-sectional R^2, and the average adjusted R^2.

For the size-B/M portfolios (Table 6, Panel A), the CAPM yielded a market price of risk that was both statistically and economically negligible ($\lambda_{MKT} \approx 0.02,\ t \approx 0.02$), accompanied by an insignificant intercept. The model explained on average about 12% of the cross-sectional variation in returns. Augmenting the specification with *SMB* and *HML* more than doubled the average R^2 (to roughly 33%) and produced a positive market lambda that was marginally significant ($\lambda_{MKT} = 1.97$, $t = 1.92$ under Shanken and $t = 2.05$ under HAC). The size factor showed evidence of a positive and significant estimated price of risk ($\lambda_{SMB} = 0.92,\ t \approx 2.05{-}2.07$), whereas the value factor commanded an essentially zero price of risk ($\lambda_{HML} = -0.10$). Extending to C4F left the qualitative picture intact: λ_{SMB} remained positive and marginally significant at 0.82, while λ_{MKT}, λ_{HML}, and λ_{WML} were all individually insignificant. Therefore, the C4F estimates did not provide evidence that market, value, or momentum exposure was priced in the size-B/M cross-section. The average R^2 rose to 38.5%, but the adjusted R^2 was essentially unchanged from FF3F, an indication that *WML* did not improve adjusted cross-sectional fit on portfolios that were not sorted on past returns.

The size-momentum portfolios (Table 6, Panel B) produced a much sharper picture and constituted the most informative cross-sectional comparison in this study. Under the CAPM, the regression yielded a strongly negative and highly significant market price of risk ($\lambda_{MKT} = -4.83$, $t = -3.47$ under Shanken and $t = -4.40$ under HAC) combined with a large positive intercept of 4.95% per month. Such a configuration was economically inconsistent with the CAPM and implied that, conditional on beta, exposure to the market factor was associated with lower expected returns. Hence in this specification the CAPM did not provide evidence of an economically meaningful description of the size-momentum cross-section.

FF3F removed this anomaly in the market lambda and substantially improved cross-sectional fit. The intercept and λ_{MKT} both collapsed to statistical insignificance, while *SMB* and *HML* produced statistically significant lambdas. The size lambda was positive and highly significant ($\lambda_{SMB} = 2.56$) and considerably larger than the unconditional mean of the *SMB* factor portfolio. The *HML* lambda, by contrast, was statistically significant but negative: $\lambda_{HML} = -4.67$, $t = -3.57$ under Shanken and $t = -4.82$ under HAC. Since the average HML return was positive, a negative *HML* price of risk did not support interpreting *HML* as a positive value-risk premium. The pattern was robust under both inference schemes, and directly relevant to the characteristics-versus-covariances debate: in this portfolio set, the *HML* beta did not behave as a positively priced source of systematic risk, even when the underlying *HML* factor portfolio earned a positive, if statistically weak, average return.

Table 6. Fama–MacBeth risk premia for the 4 × 4 size–B/M and size–momentum portfolios

Panel A: Size–book-to-market portfolios			
Shanken			
Parameter	**CAPM**	**FF3F**	**C4F**
Intercept	0.89 (0.77)	-1.40 (-1.61)	-0.81 (-0.96)
MKT	0.02 (0.02)	1.97* (1.92)	1.38 (1.36)
SMB		0.92** (2.05)	0.82* (1.86)
HML		-0.10 (-0.21)	-0.05 (-0.11)
WML			1.23 (1.30)
Avg. CS R^2	0.1206	0.3333	0.3852
Adj. CS R^2	0.0577	0.1666	0.1616
HAC			
Parameter	**CAPM**	**FF3F**	**C4F**
Intercept	0.89 (0.77)	-1.40 (-1.61)	-0.81 (-0.96)
MKT	0.02 (0.02)	1.97** (2.05)	1.38 (1.44)
SMB		0.92** (2.07)	0.82* (1.88)
HML		-0.10 (-0.22)	-0.05 (-0.11)
WML			1.23 (1.38)
Avg. CS R^2	0.1206	0.3333	0.3852
Adj. CS R^2	0.0577	0.1666	0.1616

Panel B: Size–momentum portfolios			
Shanken			
Parameter	**CAPM**	**FF3F**	**C4F**
Intercept	4.95*** (4.27)	0.12 (0.17)	-0.50 (-0.72)
MKT	-4.83*** (-3.47)	-0.25 (-0.24)	0.60 (0.74)
SMB		2.56*** (3.97)	2.23*** (3.87)
HML		-4.67*** (-3.57)	-2.16** (-2.06)
WML			1.87*** (4.60)
Avg. CS R^2	0.1170	0.3436	0.4220
Adj. CS R^2	0.0539	0.1794	0.2116
HAC			
Parameter	**CAPM**	**FF3F**	**C4F**
Intercept	4.95*** (4.27)	0.12 (0.17)	-0.50 (-0.72)
MKT	-4.83*** (-4.40)	-0.25 (-0.32)	0.60 (0.84)
SMB		2.56*** (4.69)	2.23*** (4.15)
HML		-4.67*** (-4.82)	-2.16** (-2.37)
WML			1.87*** (4.72)
Avg. CS R^2	0.1170	0.3436	0.4220
Adj. CS R^2	0.0539	0.1794	0.2116

Notes: Numbers in parentheses are t-statistics. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Source: own elaboration.

Within the size-momentum portfolios the C4F specification yielded the most economically coherent description among the three models considered. The intercept and the market lambda were both insignificant; λ_{SMB} remained positive and significant (2.23, $t = 3.87$ under Shanken and $t = 4.15$ under HAC), and λ_{HML}, while still negative, was reduced in absolute magnitude (-2.16). The main additional element was the momentum lambda: $\lambda_{WML} = 1.87$, significant at the 1% level under both inference schemes. The point estimate was also quantitatively close to the average realised return on the *WML* factor portfolio (1.61%/month), which suggests that momentum exposure carried a positive and economically consistent price of risk within this portfolio set. The average cross-sectional R^2 rose to 42.2% and the adjusted R^2 to 21.2%, improvements over FF3F that persisted after penalising the additional regressor.

The Shanken correction had only a modest quantitative effect on the *t*-statistics, and the qualitative conclusions were identical under HAC and Shanken inference. The contrast between the two test-

-portfolio sets was in itself informative: *SMB* was the only factor for which the estimated beta carried a positive and statistically significant price of risk across both sets; *WML* showed such evidence only on portfolios that varied along the momentum dimension; *HML* produced either no evidence of a positive price of risk or a statistically significant negative lambda; the market beta provided evidence of meaningful pricing only within FF3F on the size-B/M portfolios. At the same time, the adjusted cross-sectional R^2 values indicated that the models left a substantial part of the month-by-month return variation unexplained. This limits the interpretation of the Fama-MacBeth estimates to selected sources of priced cross-sectional variation, rather than being a comprehensive explanation of expected returns on the Polish equity market.

4.6. Robustness Analysis

As a robustness check, the analysis was repeated using only companies listed on the WSE Main Market, in line with previous Polish asset-pricing studies that focused on the main segment of the Warsaw Stock Exchange. The results showed that market coverage affected the strength of the evidence, but did not overturn the central interpretation. For size-B/M portfolios, the GRS statistics were lower and no longer statistically significant across the three models: 1.474 for CAPM, 1.252 for FF3F, and 1.287 for C4F. The corresponding Fama–MacBeth regressions did not provide statistically significant pricing evidence for MKT, SMB, HML, and WML. For size-momentum portfolios, the GRS test still rejected all three models, with statistics of 6.618 for CAPM, 6.137 for FF3F, and 5.879 for C4F. In the cross-section, SMB remained positive and statistically significant in FF3F and C4F, with lambdas of 1.59 and 1.11, respectively, while WML was positive and significant in C4F, with a lambda of 1.80. These results suggest that excluding NewConnect weakened the evidence for factor pricing in the size-B/M portfolios, but preserved the main size-momentum conclusion.

5. Discussion and Conclusion

This article provides a direct beta-pricing assessment of three benchmark factor models (the CAPM, FF3F, and C4F) for the Polish equity market, using a broad sample of 1,318 companies listed on the WSE Main Market and NewConnect from July 2002 to December 2025. The empirical design distinguished three questions that are often blurred in the Polish literature: whether a factor delivers a positive average return, whether it improves time-series model fit, and whether its beta commands a statistically significant and economically consistent price of risk in the cross-section.

Three findings emerged. First, multifactor models performed better than the CAPM in relative time-series fit, with the C4F specification reducing the GRS statistics on both sets of test portfolios, particularly on size-momentum portfolios, where adding *WML* cut the statistic from 7.49 (CAPM) and 7.66 (FF3F) to 5.26. In the baseline sample, the CAPM was rejected in all GRS configurations. Second, in the unconditional dimension only the momentum premium was statistically significant (1.61%/month, $t = 4.41$); the market, size, and value premia carried the expected positive signs but did not differ reliably from zero. Third, the Fama–MacBeth cross-sectional regressions delivered a nuanced picture: the strongest evidence in the analysed sample concerned size exposure, whose estimated price of risk was positive and statistically significant across both test-portfolio sets; *WML* showed evidence of a positive and economically consistent price of risk only on portfolios that varied along the momentum dimension; *HML* produced either no evidence of a positive price of risk or a statistically significant negative lambda; the market beta provided evidence of meaningful pricing only within one FF3F specification estimated on size-B/M portfolios.

Taken together, these results relate directly to the characteristics-versus-covariances debate. A positive average factor return and a successful absorption of time-series alphas need not translate into a priced source of systematic risk in the Fama–MacBeth sense. In the Polish setting, where the cross-section is dominated by small and less liquid companies exposed to liquidity and microstructure frictions, the gap between strong portfolio premiums and weak, insignificant, or wrong-signed lambdas – most visible for HML – is more consistent with characteristics, mispricing, or limits to arbitrage than with compensation for covariance risk.

Several limitations and avenues for further research emerged. Betas were estimated on the full sample and may be unstable across market phases, as suggested by Czapkiewicz and Skalna (2011); rolling-window robustness checks could refine inference. The WIG index is an imperfect proxy for an investable universe that includes NewConnect, and alternative value-weighted market proxies built from the full sample would offer a useful sensitivity test. Extending the design to five- and six-factor specifications, and to liquidity-augmented models in the spirit of Stereńczak (2021), would help clarify whether the residual size and momentum effects would survive once frictions and profitability/investment exposures were jointly controlled for.

For practitioners, the main implication is interpretive caution: size, value, and momentum may still support portfolio construction on the Polish market, but they should not be treated mechanically as priced sources of systematic risk. For investors, this means that factor-based strategies using size, value, and momentum can be useful as portfolio-formation signals, but their expected payoffs should be treated as conditional and model-dependent rather than as automatic compensation for systematic risk. Factor returns, model fit, and prices of risk are three distinct questions, and the Polish evidence reported here suggests that they need to be answered separately.

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