From Theory to Practice: Polish Equity Risk Factors and Their Implementation Costs

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Abstract

This paper investigates the performance and implementability of equity factor strategies – value, momentum, quality, and low volatility (defensive) – in the Polish stock market over the 2014–2024 period. The "academic" factors constructed as long-short portfolios are found to produce positive returns lowly (or negatively) correlated with the broad market. However, once transaction costs – including bid-ask spreads, commissions, and market impact – are incorporated, net factor returns deteriorate substantially, losing much of their appeal. The absence of a developed short-selling market in Poland further challenges the direct replication of traditional academic factor models. Despite these frictions, factor signals can still add value in a long-only framework, particularly when turnover constraints and liquidity filters are introduced. Backtests of factor-tilted portfolios demonstrate that smart beta-style implementations, especially those complemented by short positions in WIG20 index futures neutralizing market exposure, offer a viable alternative to pure long-short factor strategies.

Keywords: Equity Risk Factors, Factor Investing, Trading Costs, Market Microstructure

JEL: G11, G14, G15

1. Introduction

Ever since the seminal contribution of Fama and French (1993), it has been well understood that returns to financial assets – portfolios or strategies – are driven by exposure to multiple systematic risk premia, or "factors", proxied by various stock-level characteristics. The original Fama and French (1993) model identified two such systematic exposures – size and value – alongside the market risk factor introduced already earlier in the Capital Asset Pricing Model (CAPM) of Sharpe (1965) and Lintner (1965). The size premium reflected the extra return accruing to small capitalization relative to large capitalization stocks and the value premium rewarded for exposure to cheap vs. expensive stocks. Importantly, and unlike in the CAPM, the new risk factors were no longer thought of as passive market exposures but rather returns to active, zero-cost stock selection strategies which went long stocks that scored well on some metric – e.g. market capitalization in case of the size premium or book-to-market ratio – and short those that scored poorly.

This framework has since evolved into an extensive body of literature focused on identifying and cataloguing systematic return drivers, refining factor definitions and construction techniques as well as testing their performance in different samples and markets. And although the steady increase of potentially rewarded systematic risk premia has attracted some criticism (cf. especially Cochrane, 2011 who coined the term "factor zoo"), a subset of factors – including value, momentum, quality, and defensive (either low volatility or low beta) – has nonetheless consistently demonstrated robustness across geographies, time periods, and asset classes, while enjoying sound theoretical justification (Asness et al., 2013; Asness et al., 2019; Blitz and van Vliet, 2007; Frazzini and Pedersen, 2014; Ilamnen, 2011; and Ilmanen et al., 2021).

Given the short distance that normally separates financial research from investment practice, it should come as no surprise that the compelling evidence for the existence of factor premiums has sparked considerable interest in the asset management community and led to the development of a whole range of products geared towards systematically harvesting the style premia across markets and geographies. A particular breakthrough for factor investing came with a report by Ang et al. (2009) analyzing the performance of the Norwegian sovereign wealth fund (NBIM). The report famously found that more than two-thirds of NBIM's active returns since inception in 1998 could be attributed to factor premiums, not management skill, and concluded that NBIM should consider an explicit, strategic allocation to factor-based strategies. Although precise numbers are difficult to come by, there is some evidence that a broad spectrum of investors have heeded that advice. For example, Invesco's 2024 survey of systematic investors, together managing over $22 trillion in assets, found that 80% found factor-tilting strategies "very valuable", with value being the most widely targeted factor (90% of respondents), followed by quality (74%), momentum (69%), and low volatility (63%).

Yet, real-world implementation of factor strategies is not without challenges. Even leaving aside the issues of the reported difficulties in replicating some factors out of sample and post publication (Harvey et al., 2016; Mc Lean and Pontiff, 2016), transaction costs, both explicit and implicit, can erode the theoretically positive premium, or "alpha", of factor strategies, especially for factors which generate sizable portfolio turnover.

Thus, for example, Novy-Marx and Velikov (2016) study the gross and net-of-costs performance of a range of factor strategies for the US market, splitting strategies into low-, mid- and high-turnover groups, and find that only about a third (and none of the high-turnover ones) provide statistically significant, positive excess returns after costs (see also Korajczyk and Sadka, 2003 and Lesmond et al., 2003 who study only the momentum factor but arrive at qualitatively very similar results). Frazzini et al. (2018) have criticized the analysis by Novy-Marx and Velikov (2016) on the grounds that it relied on a theoretical model of transaction costs, and hence would not be representative of the experience of a large, sophisticated asset manager. However, studying the performance of US mutual fund managers, Arnott et al. (2017) demonstrate that factor premia actually captured by the managers are significantly lower than suggested by the theoretical long-short portfolios – a further illustration that it can be much more difficult to deliver alpha in live portfolios than on paper. The monetization of factor risk premia is complicated not just by trading costs, but also by the long-short nature of academic factors. The "paper" histories of factor return series implicitly assume that any stock can be freely shorted, while in practice some stocks may be unavailable or prohibitively costly to borrow, or – even if successfully borrowed – can be called back at any time forcing investors to cover their positions (see e.g. Jones and Lamont, 2002 on shorting constraints). These concerns underscore the gap between factor efficacy in academic research and their practical feasibility in portfolio construction, and perhaps also go some way towards explaining why factor-harvesting strategies are often implemented as factor-tilted long-only portfolios, rather than as long-short, equity market-neutral strategies. Indeed, as of end 2024, long-only factor-tilted funds boasted $2.2 trillion in assets, while only about $200 billion was allocated to equity long-short and market-neutral strategies.

While certainly relevant for developed markets, these considerations are likely to carry even more weight in Poland, whose exchange is characterized by a relatively small number of liquid stocks, state ownership in key sectors, and evolving market microstructure. Thus, although there is by now a large and growing body of literature investigating asset pricing anomalies in Poland (Czapkiewicz and Wojtowicz, 2014; Czapkiewicz and Skalna, 2011; Urbański, 2012; Zaremba,

2015; Zaremba et al., 2019 – to list but a few), factor-based strategies are yet to be embraced at scale by the domestic asset management community. A major reason behind the lack of factor investing use cases may be related to a path-breaking study of Zaremba and Nikorowski (2019) who looked at over 70 pricing anomalies across Emerging Europe, and Poland specifically, over the period 2000-201, finding that once trading costs are recognized most of those anomalies prove unprofitable, both on a long-short and long-only basis. Zaremba and Nikorowski's (2019) analysis is unique in looking at factor strategies in Central and Eastern Europe not merely from a theoretical, market-efficiency perspective, but specifically trying to pinpoint the extent of costs and frictions related to their potential real-life implementation.

However, given that the end of the authors' sample in 2015 largely preceded the robust growth of the factor investing space, it seems worthwhile to reexamine their conclusions in light of fresh empirical evidence and a more refined assessment of trading costs. This is exactly the modest goal set forth in this paper, i.e. to analyze the performance and implementation challenges associated with major equity factors looking specifically on the Polish stock market over the period 2014-2024. Although the study is directly motivated by Zaremba and Nikorowski (2019), it nevertheless departs from their methodology in a number of ways.

First, the focus is put squarely on just four factors: value, quality, momentum and low volatility, defined in the simplest, most straightforward way. Specifically, factors are constructed as returns to long-short tercile portfolios, equally-weighted, with long positions taken in the "best" 33% of stocks and short positions in the "worst" 33% stocks according to each factor screen. Although the set of potential return anomalies could turn out to be considerably greater in judiciously performed backtests, the primary focus here is on mitigating the risks of overfitting and data mining, while prioritizing risk premia with sound economic rationale, well-documented persistence and pervasiveness as well as investment relevance. Similarly, while factor definitions vary and some formulations have been shown to be more effective than others, this study intentionally employs the simplest specifications found in the literature to avoid overfitting and ensure robustness. The goal is less to document factor performance – this is something other researchers, including Zaremba and Nikorowski (2019) have looked at before – rather, it is to understand the impact of transaction costs and other frictions on factors' implementation viability.

Secondly, the sample is limited to 100 largest stocks listed on the Polish stock exchange over the period from January 2014 to December 2024. While extending backtests further in time and across a broader universe of stocks could marginally enhance confidence in factor return estimates on paper, such extensions would also complicate the assessment of real-world implementability – the central focus of this study.

Third, to understand whether the "paper" returns are achievable in practice, factor returns are adjusted for estimated transaction costs, incorporating both explicit and implicit market impact costs. Zaremba and Nikorowski (2019) consider only the former. This study relies on actual stock-level spreads and commissions estimated using data from one of the largest international funds active on the Poland and benchmarked to the MSCI IMI Poland stock index. Moreover, factor returns are also adjusted for estimated market impact of effecting portfolio trades at scale, since it is generally recognized that costs related to trade execution comprise the bulk of the actual costs of trading, especially in less liquid markets (Frazzini et al., 2018). Given the absence of real-life transaction-level execution data, market impact costs are estimated using the so called inventory risk approach initially proposed by Grinold and Kahn (1999) and later extended in multiple directions (Gatheral, 2010; Almgren et al. 2005; Kociński, 2015). Finally, given the

importance of short positions for academic factor portfolios, the study delves into data published by Polish and European supervisory authorities to assess the state of the Polish market for shorting.

In terms of results, the returns to academic factors established "on paper" are largely in line with the extant literature – at least directionally. The value factor delivers relatively weak results, in line with findings from the U.S. market over the same period (Israel et al., 2020). By contrast, the quality, momentum and defensive factors demonstrate positive returns, with the former two even outperforming the benchmark long-only WIG index while maintaining low correlation with broader market movements. While encouraging, factor strategies lose much of their initial appeal once transaction and market impact costs are properly accounted for, with the estimated strategy capacity of only around PLN 20 mn, beyond which point even momentum ceases to be profitable. Furthermore, an analysis of shorting activity in the Polish market based on regulatory data suggests that establishing and regularly adjusting short positions across all stocks identified by the relevant factor screens would not be feasible in practice. These findings are in line with Zaremba and Nikorowski (2019) and help explain why factor strategies have not thus far been adopted by the Polish investment community.

However, the substantial divergence between gross and net returns does not imply that factor signals lack value in portfolio construction. Rather, it underscores the importance of effectively managing implementation frictions. In this context, Israel et al. (2018) introduce the concept of "craftsmanship alpha," which emphasizes the role of thoughtful execution in realizing factor-based returns. To illustrate this point, the study concludes with a set of practical recommendations for constructing long-only, factor-tilted portfolios that achieves meaningful market outperformance net of estimated transaction costs across various parameter settings.

The rest of the paper proceeds as follows. Section 2 discusses the methodology behind the construction of value, low volatility (defensive), quality and momentum and presents performance results over 2014-2024. Section 3 presents the market impact model and derives net-of-costs performance estimates for the selected factors. Section 4 discusses ideas for minimizing implementation costs and shows backtest results for a reasonably realistic momentum-tilted portfolio. Section 5 briefly concludes.

2. Factor construction and gross returns

This study focuses on four popular equity factors with sound economic rationale and long histories of supporting empirical evidence across different time frames, markets and even instrument categories, i.e.: value, momentum, quality and low volatility (defensive). Before discussing the performance of each style on the Polish market, the following paragraphs cover briefly their economic (or behavioral) rationale and construction methodology.

As already hinted in the introduction, factors can be constructed in multiple ways and using different stock characteristics, which may encourage researchers to overfit their models and ultimately lead to spurious results that are unlikely to replicate in other samples or time periods (e.g., in an important recent study, Jensen et al., 2023 identify 13 broad factor themes expressed using 153 different characteristics; cf. also Harvey et al., 2016 on the problem of "p-hacking" in factor literature). Hence, to mitigate risks of data mining, this paper errs on the side of caution, and considers the simplest, most standard metrics to express each factor.

The universe for the analysis consists of 100 largest stocks (by market capitalization) over the period January 2014 through December 2024 (note that the list of stocks may change over time, with some stocks entering the universe and others leaving). The sample is notably shorter and - given that there are about 400 stocks listed on Warsaw's main market – has less breadth than in most academic factor studies. However such sample choice is deliberate and dictated by the desire to focus on institutional-scale, investable strategies, and it seemed that going much farther back and inflating the stock universe would likely add limited value in that respect (especially in view of the pessimistic conclusions derived by Zaremba and Nikorowski, 2019). Moreover, the period considered – often referred to as "quant winter" – was marked by underwhelming international performance of many factor styles. Thus, investigating the efficacy of factor investing in Poland throughout that time should mitigate the risk of arriving at overly optimistic conclusions.

Market and fundamental data is sourced from Bloomberg. Each month, stocks in the universe are evaluated based on the criteria outlined below and assigned percentile ranks,[1] with the top 33 stocks forming the long leg of the factor portfolio, and the bottom 33 stocks forming the short leg. Since no sector-neutralization is employed, which would be impractical given the small universe considered, the benchmark formulation uses equal stock weights in the long/short factor portfolios, but market-capitalization weightings were considered in untabulated tests as well and are available upon request.

2.1. Factor measures

Value

Value is perhaps the best-known systematic equity risk premium, reflecting the phenomenon that securities that appear cheap on a relative basis tend to outperform expensive ones over the long term, albeit with prolonged periods of underperformance, which has happened particularly in the last decade. Although the idea of buying cheap and selling expensive stocks had probably been around for quite some time before, it was Fama and French (1993) who documented it in a long sample of US equity data and formalized within the context of an asset pricing model. Subsequent research has confirmed the existence of a value premium in decades of out-of-sample evidence (relative to original studies), across geographies and even across different asset classes (cf. Asness et al., 2013; Asness et al. 2015, and references therein, as well as). The original justification for the existence of the value premium offered by Fama and French (1993) suggested that value stocks offer compensation for greater default risk. Yet, explanations rooted in behavioral biases, like extrapolation of past trends or delayed reaction to information, have also been proposed (Lakonishok et al., 1994; Barberis et al., 1998). Following Fama and French (1993), the traditional choice to measure value has been the ratio of a company's book value to its market price (henceforth, Book/Price, or B/P). However, acknowledging that book values can be somewhat stale (e.g. B/P can be high because the assets haven't been written down yet but market price already reflects that information), this analysis defines the value factor using a composite measure, averaging three popular ratios: Book/Price, Sales/Price, and EBITDA/Price based on trailing 12-month data. While each of these screens individually is imperfect, their average should hopefully filter out potential "value traps" and present a more comprehensive picture of the relative attractiveness of each stock's valuation.

Momentum

[1] To account for outliers, rank distributions are winsorized at +/- 2 standard deviations.

The momentum factor capitalizes on the empirical observation that stocks with strong past performance tend to continue outperforming, while underperformers persist in lagging. This pattern, first documented by Jegadeesh and Titman (1993) and reinforced by subsequent research, has proven to be one of the most robust anomalies across different asset classes and geographies (Asness et al., 2013; Zaremba et al., 2019). The persistence of momentum returns – and hence its systematic character in explaining stock returns – is typically attributed to behavioral factors such as investor underreaction to new information and delayed price adjustments (Hong and Stein, 1999; Barberis et al., 1998). From a risk-based perspective, momentum may reflect compensation for the higher volatility of high-momentum stocks driven by greater growth potential in earnings, which in turn implies more sensitivity to economic shocks. A typical approach to measuring momentum involves using the past 12-month total return, however acknowledging the research that points to strong short-term momentum effects, this study defines momentum as the average of a stock's trailing 6-month and 12-month total returns, skipping the most recent two weeks to avoid spurious short-term reversal effects.

Quality

The quality factor captures the idea that companies with strong financial health—high profitability, stable earnings, and conservative balance sheets—tend to outperform their lower-quality counterparts over time (Novy-Marx, 2013; Asness et al., 2019). Unlike value, which focuses on price relative to fundamentals, quality measures a firm's fundamental strength directly. Asness et al. (2019) argue that quality stocks command a premium because they are more resilient in economic downturns and less prone to financial distress. However, investor preferences for speculative, high-growth stocks often lead to an underpricing of quality companies, creating opportunities for long-term outperformance. In this study, quality is defined as a composite measure incorporating both profitability and (low) leverage: profitability is measured as the average of Return on Equity (ROE) and Return on Invested Capital (ROIC), while leverage is defined as debt-to-market capitalization, with all metrics based on trailing 12-month data, with the quality score being proportional to earnings and inversely related leverage.

Low Volatility (Defensive)

The low volatility, or defensive, factor is based on the anomaly – discovered already by Black et al. (1972) – that stocks with lower historical price fluctuations tend to offer higher risk-adjusted returns than their more volatile counterparts. Although seemingly paradoxical – higher volatility should theoretically be rewarded with higher expected returns – the phenomenon has been documented in multiple samples and tested using different risk measures, including total and residual volatility and even CAPM beta (Ang, et al., 2006; Blitz and Vliet, 2007; Frazzini and Pedersen, 2014). Most accounts attribute the low risk anomaly to constraints faced by institutional investors – such as leverage and short-selling restrictions – which lead them to seek high-return opportunities in riskier stocks, inadvertently causing low-risk stocks to be systematically undervalued. Additionally, behavioral biases, such as investor overconfidence and lottery-like preferences, contribute to the mispricing of high-volatility stocks. The defensive factor in this study is constructed simply as the average of a stock's trailing 6-month and 12-month volatility, measured as the standard deviation of daily returns. Unlike in previous instances, here a higher factor score should actually be inferior, and therefore stocks are sorted and percentile ranks assigned in ascending order (lowest to highest).

2.2. Gross performance of factor portfolios

Table 1 reports performance statistics, including mean arithmetic returns, return volatilities and Sharpe ratios, for the factor portfolios constructed as outlined above. Results for each style are broken down by stock terciles which form the long and short legs in the final long-short factor. The rightmost column additionally shows the correlation of each strategy to the broad equity market represented by the benchmark WIG index. Recall that these initial tests do not account for trading costs or other market frictions – the goal here is to explore the basic existence of factor premia on the Polish market before addressing the degree to which they are investable in the in the following section.

Table 1. Summary Statistics of Equity Risk Factors in Poland (2014-2024)

		Mean return(%)	Volatility (%)	Sharpe ratio	t-stat	Correlation to WIG
Market	WIG	6.04	18.23	0.33	1.05	1.00
Value	Top tercile	7.30	18.72	0.39	1.23	0.85
	Bottom Tercile	7.92	16.24	0.49	1.54	0.76
	Top-Bottom	-0.62	14.54	-0.04	-0.14	0.24
Momentum	Top tercile	17.68	17.34	1.02	3.22	0.75
	Bottom Tercile	-2.68	20.06	-0.13	-0.42	0.87
	Top-Bottom	20.36	16.22	1.26	3.97	-0.27
Quality	Top tercile	11.92	14.44	0.83	2.61	0.75
	Bottom Tercile	4.82	18.97	0.25	0.80	0.89
	Top-Bottom	7.10	13.46	0.53	1.67	-0.45
Defensive	Top tercile	7.82	12.63	0.62	1.96	0.86
	Bottom Tercile	5.51	20.18	0.27	0.86	0.84
	Top-Bottom	2.31	12.28	0.19	0.60	-0.49

Note: factor universe comprises 100 largest stocks listed on the main market of the Polish stock exchange; factors defined as in section 2.1; mean returns are arithmetic averages; Source: Bloomberg data.

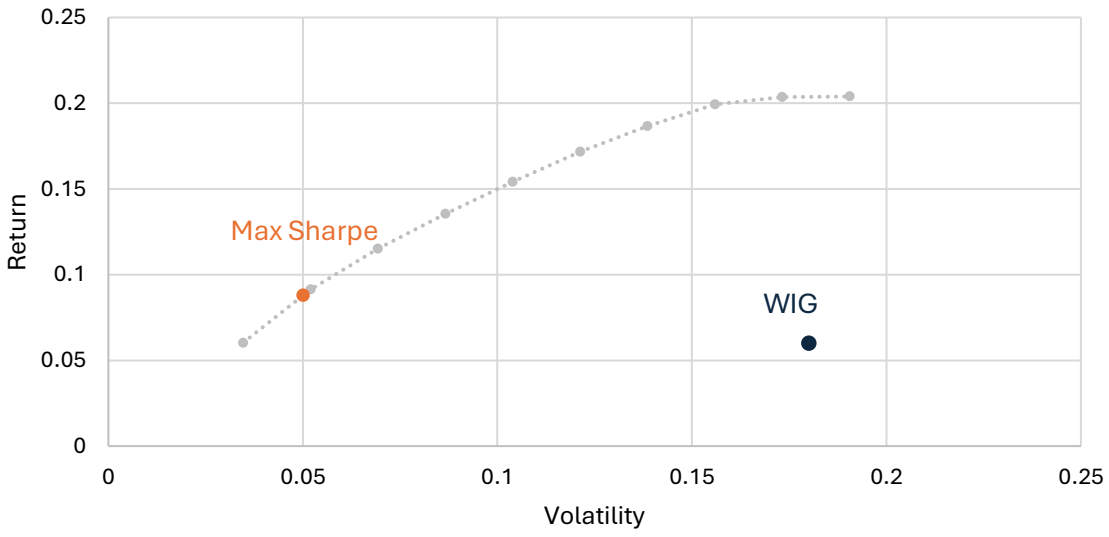
Although broadly supportive of factor premia, the empirical results presented in Table 1 show some divergence in performance across styles. The value factor appears ineffective, with the top tercile yielding an average return of 7.30% and the bottom tercile slightly higher at 7.92%, resulting in a negligible long-short return of -0.62% and an insignificant Sharpe ratio of -0.04. This aligns with international evidence suggesting that value strategies have faced persistent headwinds in recent years (Israel et al., 2020). Indeed, Fama and French's HML value factor (size-adjusted) recorded a mean return of -2.13%, with significant underperformance of the high B/M stock deciles, and the top tercile stocks underperforming the bottom tercile by 0.27%.

In contrast, the momentum factor exhibits strong and statistically significant performance, with the top tercile generating 17.68% annualized returns versus -2.68% for the bottom tercile and 6.04% for the WIG. The long-short momentum portfolio delivers an impressive 20.36% return with a Sharpe ratio of 1.26, reinforcing the robustness of momentum as a return-generating anomaly, consistent with prior findings in global markets.

The quality and defensive factors also demonstrate favorable risk-adjusted performance. High-quality stocks deliver an annualized return of 11.92% compared to 4.82% for low-quality stocks, resulting in a statistically meaningful long-short premium of 7.10% and a Sharpe ratio of 0.53. The defensive factor, constructed using historical return volatility, also exhibits positive but modest performance, with low-volatility stocks returning 7.82% versus 5.51% for high-volatility stocks, yielding a long-short return of 2.31%.

Importantly, all four factors are lowly or even negatively correlated to the broad market index, suggesting that diversifying equity exposure across factor strategies might improve portfolio efficiency. To verify this, a simple Markowitz-style optimization is performed, whereby the optimizer allocates across the market beta (WIG) and the four long-short factors solving for weights which maximize return for a given level of risk. The results of this exercise, plotted in Figure 1, demonstrate that a theoretical portfolio fully invested in WIG lies well below the efficient frontier and is thus not efficient by any means. In contrast, the Sharpe ratio maximizing portfolio allocates only about 20% to the broad market beta, with the remained spread roughly across all four factors (30% to the momentum factor and between 14% and 18% to quality, defensive and value factors). The allocation to value might be particularly surprising given its moderately negative performance. However, its positive portfolio-level contribution stems from strong negative correlation with other factors, and particularly so with momentum (-0.5). Overall, these results suggest that there is a clear investment case for incorporating Polish equity factor screens in portfolio construction, a point that aligns well with both practitioner and academic evidence from other markets. However, the key question is whether this still holds once transaction costs are properly accounted for – a point addressed below.

Figure 1. Mean-variance optimization involving Value, Momentum, Quality and Defensive



Note: Mean-variance optimal portfolio comprises a 20% allocation to the broad market (WIG), 31% to momentum, 18% to value, 14% to quality and 17% to low-volatility (defensive); see section 2.1 for factor definitions. Source: data Bloomberg.

3. Factor implementation constraints: trading costs and shorting frictions

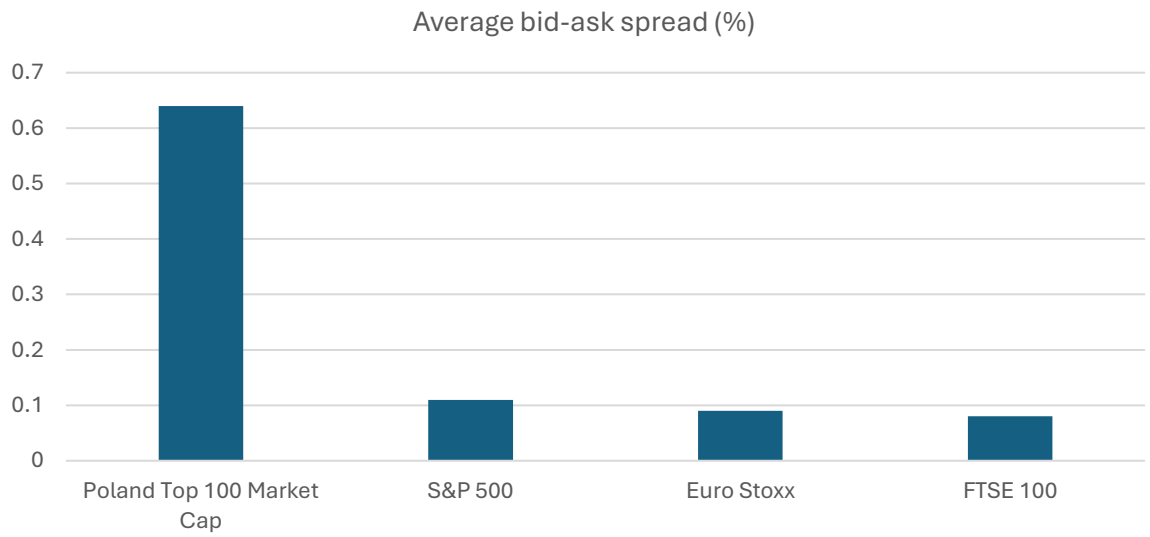
Accurately assessing transaction costs is critical in evaluating the real-world implementability of factor-based investment strategies. Given the relatively lower liquidity of the Polish equity market

compared to major developed markets, transaction costs could materially affect realized factor returns, particularly for high-turnover strategies like momentum which seems to exhibit truly remarkable performance on a gross-of-costs basis.

Following the approach outlined in the literature (Frazzini et al., 2018), this study incorporates both explicit and implicit trading costs to estimate net returns for long-short factor portfolios. Explicit costs refer to directly observable costs such as bid-ask spreads and brokerage commissions, typically known ex ante before a trade is initiated, while implicit costs account for the market impact of executing trades at scale.

The analysis in the previous section used a single price for evaluating the performance of all factor strategies and thus presented an unrealistically optimistic picture of performance because it abstracted from the fact that a trader will typically only be able to sell around the bid and buy at the ask side of the market. Thus, the spread between bid and ask prices will naturally depress performance relative to a benchmark index constructed using the mid (i.e. half-way between bid and ask) or close prices for a given day (like the WIG index above).[2] For this study, bid-ask spreads are estimated based on historical price data for the stocks included in the analysis as reported by the exchange and sourced from Bloomberg. Despite truncating the trading universe to the top 100 listed companies, bid-ask spreads on the Polish exchange are non-negligible especially when compared to the US or even biggest European exchanges.

Figure 2. Bid-ask spreads for the top 100 companies listed on the Polish stock exchange vs. spreads for stock universes covered by major US and European indices.



Source: Bloomberg data.

Buying and selling securities during each monthly rebalancing involves paying brokerage commissions. In practice these can vary depending on the economies of scale and specific business arrangements between the manager and the broker. To retain some degree of realism, this study uses actual brokerage commissions reported by BlackRock in managing its EPOL ETF benchmarked to the MSCI IMI Poland Index, which is one of the largest international funds

[2] Specifically, each trade is assumed to cost half of the prevailing bid-ask spread which is a conservative assumption. In practice, economies of scale might result in managers being able to transact at closer to 1/3 of the spread.

invested in Poland with almost PLN 1 bn exposure on the domestic market. The data reported by the fund shows the degree of portfolio turnover, overall volume of trading index securities, and the commissions paid in a given fiscal year. For example, throughout the year 2024, the fund effected a turnover of 11% of its roughly $300 million portfolio of in 32 securities, paying $54 thousand in commissions, or effectively about 2 basis points (with similar numbers in preceding years). This number is an order of magnitude smaller than the estimate used by Zaremba and Nikorowski (2019) in a similar context, which might reflect both the institutional economies of scale reaped by BlackRock as well as to some extent the evolution of the market.

It is in general more challenging to incorporate implicit transaction costs which are not known ex ante and primarily attempt to measure the instantaneous price change induced by executing an order. The idea behind market impact costs is that the price at which a trade can be effectively executed will likely differ from the price that exists when a trade begins in the market (often called "arrival price"), with the difference – implementation shortfall – reflecting factors like the size and character of the instrument traded, timing, market activity upon execution and even the trader's operational facilities, algorithms and skill in positioning orders. Without access to a database of live trades executed at scale on the Polish exchange, this paper relies on a simple model-based estimate of market impact inspired by the inventory risk approach initially proposed by Grinold and Kahn (1999) and later extended in multiple directions (Gatheral, 2010; Almgren et al. 2005; Kociński, 2015).

The model estimates market impact based on the risk borne by the market maker (liquidity provider) facilitating the trade. For completeness, here's the argument in broad strokes. For a given order size, the estimated time it will take the liquidity provider to find enough opposite trades to clear out the acquired inventory (i.e. a stock, or a stock portfolio) is given by:

$$t_{clear} \propto \left(\frac{Order\ Size}{ADV}\right)$$

where ADV is the average daily volume in the stock. So, roughly, it should take one day to trade one day's worth of volume. The time t_{clear} between taking on and disposing of the inventory exposes the liquidity provider to risk which is related to the stock's volatility over the relevant time frame (assuming t_{clear} is measured in days and there are 250 days per year):

$$\sigma_{invenory} = \sigma\sqrt{\frac{t_{clear}}{250}}$$

with σ being the stock's volatility. Finally, market makers will require some compensation for facilitating trades, the extent of which should again be proportional to the risk borne in the process:

$$\frac{\Delta P}{P} \sim \sigma\sqrt{\frac{t_{clear}}{250}} \sim \frac{\sigma}{\sqrt{250}}\sqrt{\frac{Order\ Size}{ADV}}$$

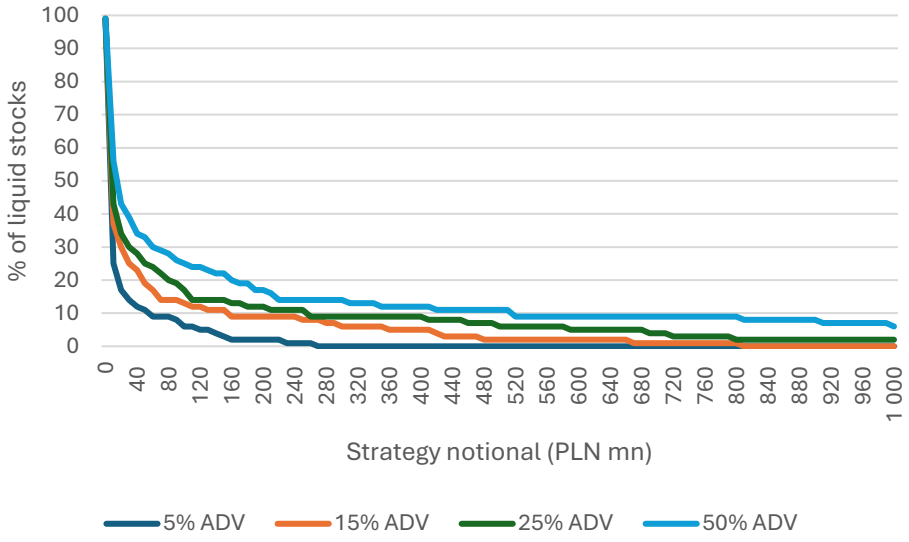
Thus, the model predicts that it should cost roughly one day's volatility to trade one day's volume in a given security, which despite its simplicity has been found to fit actual trading data relatively well (e.g. Toth et al. 2011 confirm the square-root market impact formula using a large sample of proprietary trades executed by a large Europe-based hedge fund).

Taking into account both the explicit and implicit component, the overall trading cost estimate for a trade is thus given by:

$$Cost = commision + \frac{bid - ask\ spread}{mid\ price} + \frac{\sigma}{\sqrt{250}}\sqrt{\frac{Order\ Size}{ADV}}$$

It follows that quantifying the amount of trading costs paid upon each rebalancing trade requires making an assumption about the size of the order placed in a stock relative to its average daily volume, and therefore ultimately about the notional amount allocated to the strategy. In a live setting, portfolio managers might attempt to control slippage by limiting their trades to a fraction of average daily volume, a common choice being 15%-20%, which would allow to trade roughly 1 million per day in virtually all stocks in the STOXX 600 index.

Figure 3. Fraction of liquid stocks under different ADV constraints and notional (top 100 stocks by market capitalization listed on Warsaw stock exchange; December 2024)

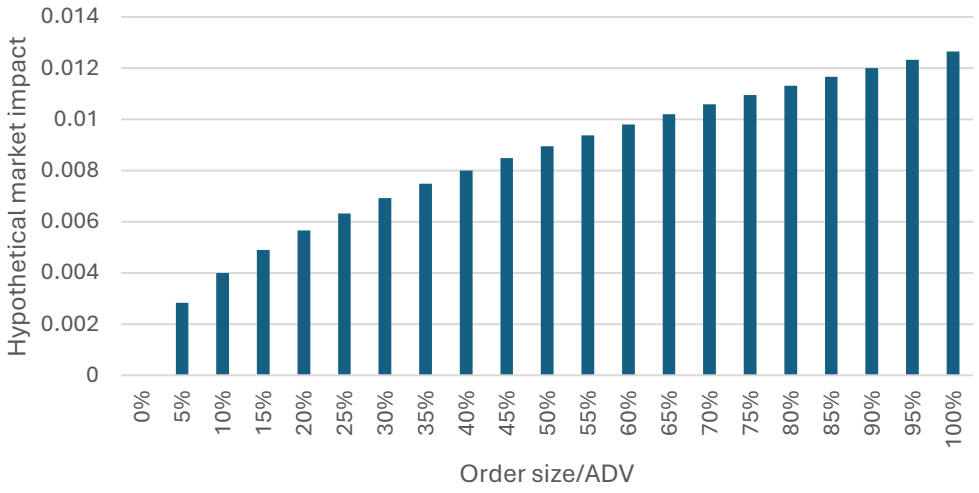


Note: ADV is 30-day average volume; changing horizon length for ADV calculations did not lead to material changes in results; Source: Bloomberg data.

A similar exercise would not be possible for stocks used in this backtest, however. Figure 3 shows that by PLN 150 mn in assets, 90% of stocks fail the 15% ADV liquidity test and 80% fail the 50% ADV liquidity test, implying market impact costs exceeding 0.6% and 0.9% of notional traded respectively (Figure 4).[3] On the other hand, capping strategy notional at PLN 1mn, which would allow trading most stocks in the universe relatively easily, does not seem to be a realistic representation of a viable financial product (the median assets under management for Polish equity mutual funds is PLN 80 mn, with the lowest quintile equal to 20 million).

[3] To ensure robustness, these results were benchmarked against Bloomberg's proprietary ex ante transaction costs model, showing broad alignment across securities and notional figures. For example, according to Bloomberg's Transaction Cost Analysis function, trading 40,000 shares of Orange Polska SA (OPL PW) at 15% participation rate would take about an hour and generate a cost of 35 bp. The square-root model proposed above estimates the market impact costs at a slightly lower level of about 25 bp.

Figure 4. Estimated market impact as a function of order size for a hypothetical stock with annualized volatility 20%



Note: market impact calculations based on the inventory risk approach relating volatility to square root of relative order size.

Thus, to give a reasonably broad view of the potential capacity constraints facing academic factor implementations, Table 2 presents net returns calculations for the four styles, with market impact cost estimates for a range of strategy notional values of between PLN 1 mn and PLN 200 mn.

Table 2. Mean returns for equity factors net of spreads, commissions and estimated market impact costs for a range of assumed notionals (2014-2024)

Factor/Strategy notional		1 mn	10 mn	20 mn	50 mn	100 mn	200 mn
Value	Top tercile	5.80	4.48	3.68	2.10	0.31	-2.21
	Bottom Tercile	6.60	5.43	4.72	3.32	1.74	-0.49
	Top-Bottom	-3.44	-5.93	-7.43	-10.42	-13.79	-18.54
Momentum	Top tercile	13.89	10.56	8.53	4.52	0.00	-6.39
	Bottom Tercile	-6.34	-9.57	-11.53	-15.41	-19.78	-25.96
	Top-Bottom	12.91	6.35	2.37	-5.52	-14.42	-26.99
Quality	Top tercile	10.63	9.49	8.80	7.44	5.90	3.72
	Bottom Tercile	3.37	2.10	1.33	-0.21	-1.93	-4.38
	Top-Bottom	4.36	1.95	0.49	-2.41	-5.67	-10.29
Defensive	Top tercile	6.03	4.46	3.50	1.61	-0.53	-3.55
	Bottom Tercile	3.17	1.10	-0.15	-2.62	-5.42	-9.37
	Top-Bottom	-1.82	-5.46	-7.66	-12.04	-16.96	-23.94

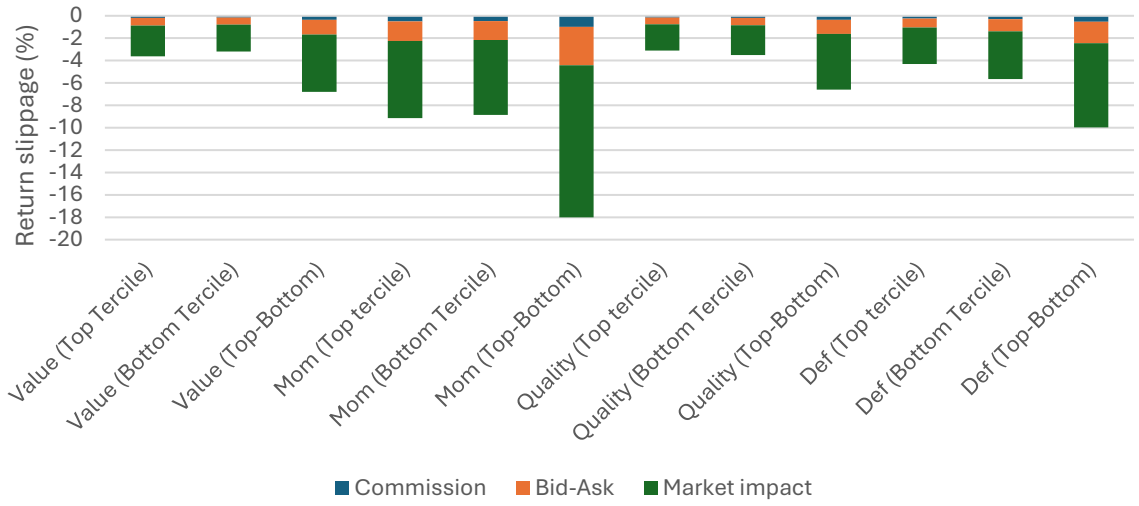
Slippage resulting from the incorporation of transaction costs is very pronounced, depressing the returns to long sides of the portfolios (top and bottom) by 700 basis points on average, and the

long-short styles by twice that amount, although this does not include shorting costs or the interest earned on the proceeds from the short sales held as collateral. Capacity constraints begin to bite relatively quickly and by the 50 mn mark even momentum stops being viable. These results contrast strongly with evidence from the US market, where the breakeven fund sizes for Fama-French long-short factor portfolios have been estimated by various authors at $2-$5 bn (Korajczyk and Sadka, 2004) or $50-100 bn (Frazzini et al., 2017), which is admittedly a broad range, but nevertheless points to capacities roughly 2-3 times larger.

In line with intuition, long-short implementations come out significantly worse than any of the long legs, which reflects the fact that in line with the academic methodology, factor portfolios are designed to take full advantage of leverage and as a result long-short portfolios generate about twice as much trading activity as their long-only counterparts. Thus, a 10 mn strategy notional means that investor buys 10 mn worth of securities and sells short an equal amount.[4] Predictably, as well, the impact of trading costs is a function of portfolio turnover – momentum portfolios (top and bottom deciles) generate average turnover rates of over 20% per month, i.e. 2-3 times higher than the other styles (these numbers are broadly in line with those reported by Novy-Marx and Velikov, 2016).

To shed more light on the drivers of the implementation shortfall, Figure 5 shows a breakdown of slippage (defined as the spread between net and gross returns) assuming fixed notional of 20 mn for all strategies. Perhaps unsurprisingly, and in line with the literature, commission turns out to be the least important cost element, followed by the bid-ask spread. What really drives slippage is market impact which reflects the fact that academic factor portfolios are not designed to address liquidity, turnover of costs in any way. To the contrary – in some cases, strategies negatively select, whereby a factor score is high – and the stock gets included in the portfolio – precisely because its liquidity might be very low.

Figure 5. Decomposition of return slippage (net-gross returns) by cost category for 20mn notional



[4] Leverage need not be an inherent feature of a long-short implementations. Given capital of 10 mn and striving to control trading costs, a manager might decide to keep half in risk-free securities, use the remaining half to buy stocks for the long side of the strategy, and short a corresponding amount, which would generate turnover comparable to a 10 mn long-only implementation.

Importantly, the underwhelming results for long-short portfolios reported above do not yet take into account shorting constraints. Specifically, the returns are net of trading costs, but it is still implicitly assumed that any stock with a low enough factor score to be included in the short leg can in fact be borrowed and held for a month until the next rebalancing. Neither of these assumptions needs to hold in practice: shares the portfolio manager intends to short may simply not be available for borrowing and can be called back by the lender virtually at any time.

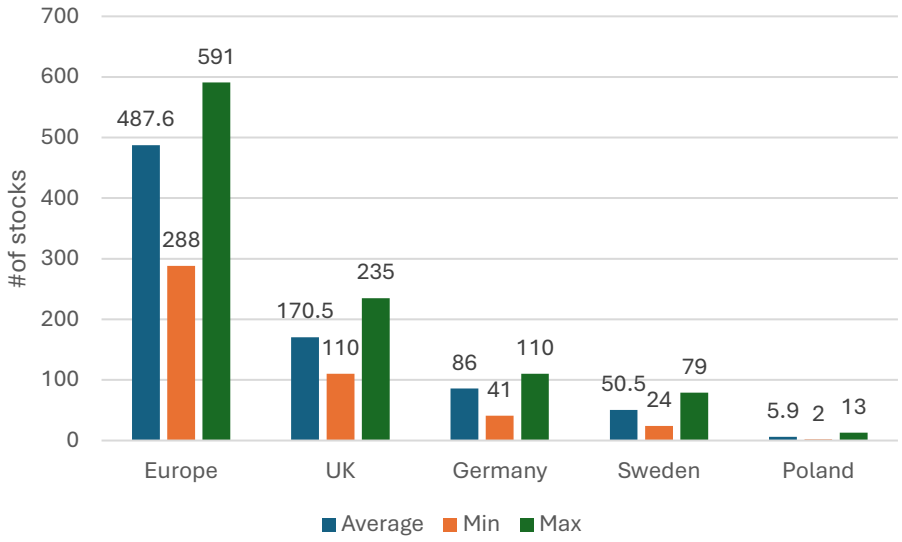
While it is difficult to assess with any certainty the extent to which these frictions currently impede shorting Polish stocks, severe restrictions were definitely in place at the very beginning of the sample. From 2010 to 2015, short selling in Poland was allowed only for the 20 largest stocks included in the benchmark WIG20 index and shares outside WIG20 could be added to the list provided they had an average daily trading volume of over PLN 4 mn – a tall order given that ADV for the currently most liquid stock (Bank PKO, PKO PW) is around 3 mn. Furthermore, any stock that made it to the shorting list could be withdrawn from it (requiring immediate closeout of any outstanding positions) in case of a perceived deterioration of market liquidity or a significant drawdown in the WIG20 or some of its constituents. There is no publicly available record of the extent of short selling for that time but given the narrow scope of the short selling list, it is clear that it would not have been possible, legally or practically, to form the short legs of diversified academic factor portfolios.

By May 2015, 18 months into the current sample, new regulations came into force, transposing the EU regulation on short selling[5] into domestic law. The new regulatory regime revoked the old liquidity restrictions replacing them with a uniform standard across the EU, which prohibits uncovered (naked) short sales and puts in place a common reporting standard, whereby any short positions exceeding 0.1% of a company's share capital are to be reported to the local supervisory authority and disclosed publicly if they exceed 0.5% of share capital. Although limited to sufficiently large positions, the supervisory database still gives some, albeit imperfect, idea of the extent of shorting activity on the Polish stock exchange in comparison to other European markets.

According to the supervisory data, as of December 2024, investors maintained only 12 short positions in 8 unique companies listed on the Polish stock exchange. The biggest number of short positions – 19 – was reported in early 2017, in a total of 13 companies. Throughout 2015-2024, on average investors shorted stocks of just 6 companies. This pales in comparison with the most active European markets, where investors shorted on average between 171 (UK) and 51 (Sweden) stocks. Across Europe, on average 488 stocks were shorted on any given day in the period 2015-2024, ranging from a minimum of 288 and a maximum of 591 (Figure 6).

[5] Regulation (EU) No 236/2012 of the European Parliament and of the Council of 14 March 2012 on short selling and certain aspects of credit default swaps.

Figure 6. Shorting statistics for selected European markets



Note: the numbers include only positions exceeding 0.5% of share capital as reported to regulatory bodies and disclosed publicly in line with EU Regulation No 236/2012; Source: KNF, national supervisory bodies; finaristo.com.

In and of itself, the data does not prove conclusively that it would be impossible to short a much broader range of listed securities. However, the fact that over the past decade sizeable short positions were maintained in just a fraction of the investable universe does seem to suggest that shorting constraints – in one form or another – are present on the Polish market and that building portfolios with short positions in 30 stocks (out of the pre-filtered subset of the largest companies), as required by the academic factor methodology, could be unrealistic. It follows, therefore, that even the net-of-costs performance of long-short portfolios reported above is likely not attainable in real life implementations.

However, Table 1 suggests that in line with the findings reported by Blitz et al. (2020), much of the value added generated by long-short portfolios originates on the long side (i.e. top tercile), with the short side offering a relatively weaker premium. Indeed, for all four factors the long legs outperform the broad market benchmark index on a gross-of-costs basis by between 1.3 percentage points in case of value and almost 12 percentage points for momentum. Similarly, the outperformance of the long legs relative to the WIG is higher than the underperformance of the short legs (except for value where the long-short portfolio exhibits negative returns and is salvaged in portfolio context only by its low correlation to the broad market). These results suggest that even though long-short implementations remain beyond the reach of investors on the Polish market[6], exposure to factor premia could still potentially be sought through long-only portfolios.

4. Efficient long-only factor implementations: the case of momentum

Although a long-only style premium strategy bypasses the obstacles related to shorting, in its raw academic form it would still likely face significant alpha decay once strategy size, market impact and transaction costs are properly factored in. Indeed, while the top tercile portfolios outperform the market by roughly 5 percentage points, on average, gross of costs, that flips to a 2-percentage-

[6] This is not to say that selected Polish stocks cannot play a role in global or pan-European long-short strategies harvesting style premia, where they would necessarily be part of a much bigger universe. In fact, some of the firms that have revealed shorting Polish-listed stocks specialize in managing just such globally diversified funds (e.g. AQR Capital Management).

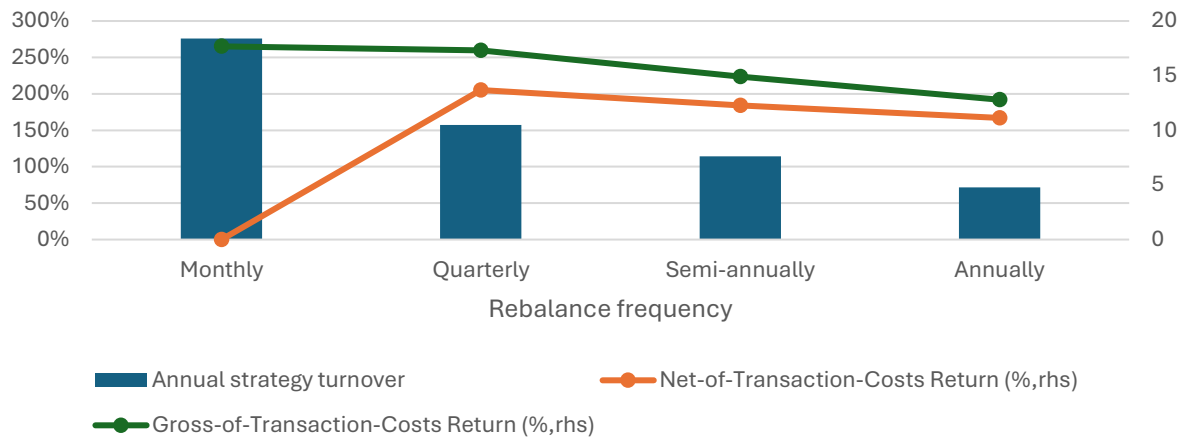
point underperformance by the time strategy notional reaches 50 mn and market impact costs are included. Nowhere is this more apparent than in the momentum strategy which operates at a monthly turnover about twice as high as other strategies, and therefore suffers greater implementation slippage (Figure 5).

Against such background, this section looks at potential ways of salvaging the style premia in long-only portfolios through more thoughtful portfolio construction and implementation. The first very crude approach of limiting slippage is to stick to the original factor construction methodology and universe introduced above but simply rebalance less frequently, trading off portfolio "freshness" for lower transaction costs.

Consider momentum as the starkest example. Each monthly recalculation of factor scores leads, on average, to the sale of 6-8 stocks (out of the 32-33 stock top tercile portfolio) which are then replaced by an equal number of new ones, leading to annual transactions volume of almost 3 times the strategy market value. This is natural, as what screened well, i.e. was growing particularly fast, a month ago may no longer do so the following month. Although it might be naively thought that adjusting portfolio weights less frequently would simply mean more trading at a later date, e.g. three times the monthly number of stocks sold per quarter etc. However, by trading less frequent, the strategy avoids selling securities mid-year which might need to be repurchased at a later date. As a result, moving to quarterly rebalancing cuts the annual turnover roughly by a factor of two, and with annual rebalancing transactions volume drops further by a factor of 4.

These lower turnover figures translate directly to cost savings. Recall that with PLN 100 mn notional, the net return of the top-tercile momentum portfolio rebalanced monthly was just 0.0%, over 17 percentage point degradation in performance relative to the gross version (Tables 1-2). With quarterly rebalancing the net performance picture changes dramatically as return jumps to 7.2% (Figure 7). Lower rebalance frequencies do improve returns further, to 7.6% and 8.2% respectively, but the incremental gains are clearly much less spectacular. This is to be expected and reflects performance degradation resulting from holding a more stale portfolio which progressively loses its momentum tilt. To get a sense of style drift, Figure 7, includes also the gross performance of the top tercile momentum portfolio for different rebalance frequencies showing a steady decline from 17.7% (monthly) to 12.8% (yearly). Overall, it would seem fair to conclude that while turnover control through rebalancing frequency is certainly crucial to any successful factor implementation, it likely isn't the full story as the cost of trading needs to be weighed against the opportunity cost of not trading (keeping more stale positions) – perhaps through some dynamic optimization process (Isreal et al. 2018).

Figure 7. Turnover of the long leg of the momentum portfolio against net and gross returns for different rebalancing frequencies

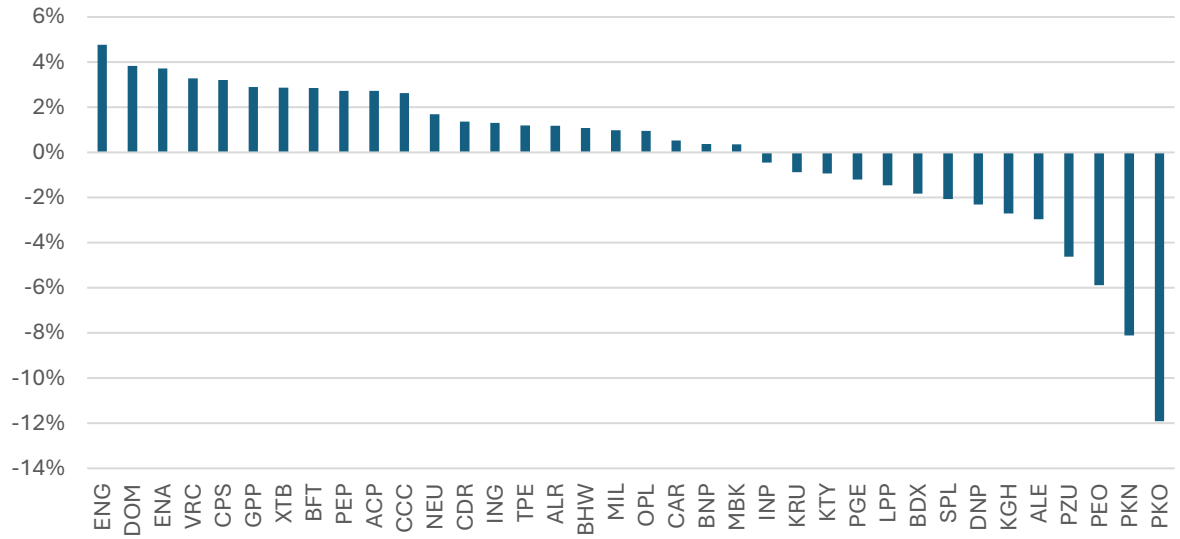


Note: Momentum portfolio is the long-only portfolio of stocks with top-tercile momentum scores; turnover and return figures are annualized; cost estimates assume 100 mn notional.

Another approach to mitigating trading costs could involve restricting the investment universe to the largest, most liquid stocks while introducing systematic deviations from market capitalization weights. While there can be multiple ways of truncating the sample based on liquidity criteria, a quick and easy solution is to use the universe included in the MSCI Investable Market Index Poland which comprises some 30 stocks accounting for 99% of the free float-adjusted market capitalization in Poland. The additional benefit of this approach is that the MSCI IMI index serves as a benchmark for one of the largest international funds providing exposure to the Polish market (i.e. the EPOL fund managed by BlackRock already used above for calibrating commissions), providing a natural point of reference for assessing the potential value added of any factor tilts in the universe. Throughout 2014-2024 EPOL delivered a mean (local currency) return of 4.6% at a volatility of 20% and boasted average assets under management of PLN 960 mn. Furthermore, to preserve the "freshness" of factor signals, the portfolios will be rebalanced monthly with positions sized such that the weight of each stock is proportional to its most recent factor score. Such "smart" factor-based benchmark tilts are often called "smart beta" and constitute a large portion of the mutual fund/ETF landscape in the United States and Europe (see Kahn et al. 2014 for an overview of the concept and product landscape).

Figure 8 shows the extent of active position tilts – i.e. the under/overweights in each stock relative to the passive EPOL fund – for such a "smart beta" construction of momentum factor using a snapshot of portfolio composition as of December 2024. The momentum-screened portfolio is clearly underweight in the most liquid stocks like PKO Bank, PKN Orlen and PZU, which is likely to inflate trading costs, but these may well be more than offset by the extent to which portfolio tilts succeed in capturing the factor premium. Thus, Table 3 zooms in on the performance of long-only factor portfolios designed as active tilts relative to the MSCI IMI Poland index. As before, to estimate transactions and market impact costs, the calculations assume different strategy assets – ranging from a mere 10 mn to 1 bn.

Figure 8. Portfolio allocations of a hypothetical momentum-tilted portfolio vs. MSCI IMI Poland (portfolio snapshot as of December 2024)



Note: Momentum-tilted portfolio allocates to stocks included in the MSCI IMI Poland index based on momentum factor score defined in section 2.1.

Table 3. Net-of-costs performance of factor-tilted long-only portfolios (2014-2024)

	Long-only factor portfolios returns (%)			
Notional (PLN, mn)	Value	Mom	Quality	Defensive
10	8.24	11.64	8.50	7.62
20	8.08	11.27	8.34	7.41
50	7.77	10.54	8.00	7.00
100	7.41	9.71	7.63	6.55
200	6.91	8.54	7.11	5.90
1000	4.78	3.59	4.88	3.16

Note: mean arithmetic returns; strategies allocate to the stocks included in the MSCI IMI Poland index based on the respective factor scores defined in section 2.1.

The first thing to note is that unlike the top-tercile portfolios which tended to lose money by the time strategy assets reached 100 mn (Table 2), each of the investable factor strategies delivers positive returns even when deployed at a relatively large notional. Despite a markedly narrower universe, monthly-adjusted factor score weights capture enough of a premium to help the four portfolios outperform the passive EPOL fund, at a slightly lower volatility (16.8%-18.9% across notional scenarios vs. 20% for EPOL). Even at PLN 1 bn, which would correspond to the 95-th percentile of Polish funds' assets under management, value and quality-tilted portfolios deliver a 20-30 bp pickup relative to the passive benchmark. This is not to imply that there is no size-related alpha decay or that the simple portfolio construction suggested above exhibits no scalability issues. The factor portfolios still generate annual turnover of between 6 and 14 (in the case of momentum) times that of the passive EPOL fund which naturally erodes performance due to market impact effects. However, the results presented thus far do suggest that long-only Polish

factor portfolios should be investable and profitable at a realistic scale – especially when further portfolio construction enhancements are resorted to.

One drawback of the long-only construction is that while it can be used to capture some (or even most) of the factor premium through systematic deviations from market capitalization weights, the premium itself comes bundled up with a broader market exposure. Indeed, the investable factor portfolio correlations to the EPOL/MSCI IMI Poland are all well above 0.9, which suggests that while these long-only implementations can be thought of as a source of excess return relative to the benchmark, they cannot be expected to provide any diversification benefits.

To address this shortcoming, in the final round of backtests individual factor portfolios were coupled with a short position in the WIG20 Index futures. The contracts are fairly liquid with an average daily volume of over 25 thousand contracts (as of December 2024) which corresponds to roughly PLN 1.5 bn in notional exposure. Given that the long-only portfolios exhibit in-sample betas of roughly 0.8 to the market benchmark, the short exposure to the front month future is rebalanced monthly to be equivalent to 0.8 of the notional of the cash equity leg.

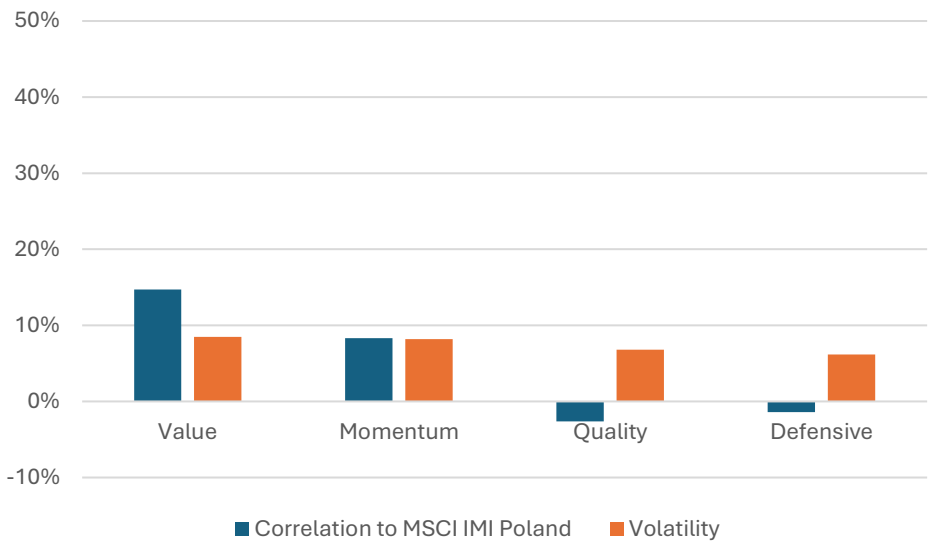
Table 4. Net-of-costs performance of factor-tilted portfolios with neutralized market exposure (2014-2024)

	Market-neutral factor portfolios returns (%)			
Notional (PLN, mn)	Value	Mom	Quality	Defensive
10	5.43	8.83	5.69	4.80
20	4.74	7.93	4.99	4.07
50	3.37	6.14	3.61	2.61
100	1.82	4.12	2.05	0.96
200	-0.36	1.27	-0.16	-1.37
1000	-9.58	-10.77	-9.48	-11.20

Note: the long legs of the portfolios are as in Table 3; the neutralization of broad market exposure achieved via a short position in WIG20 index futures rebalanced monthly to be equivalent to 0.8 of the notional of the cash equity leg.

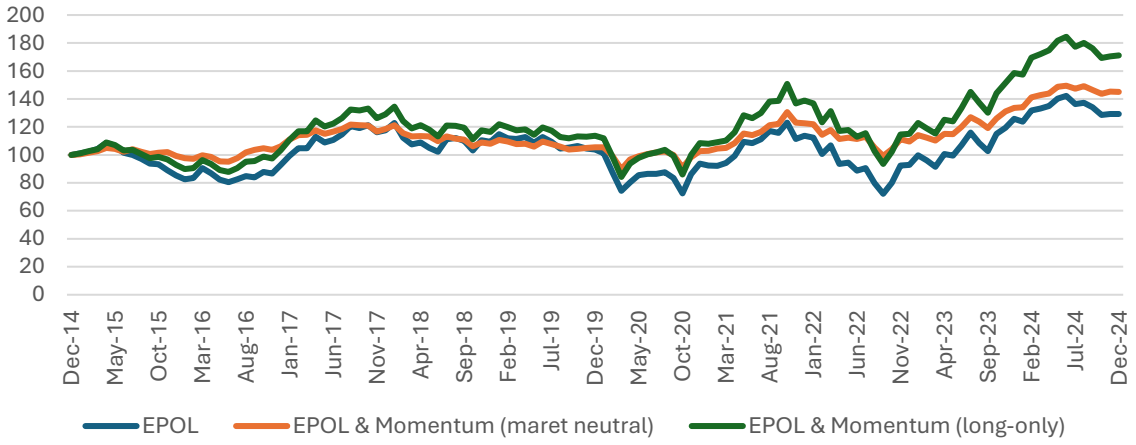
Table 4 presents return statistics for the four factors with neutralized market exposure. As before results are broken down by strategy notional to incorporate transaction costs (on both the cash equity and futures leg). In addition, Figure 9 shows average correlation to the market benchmark and volatility averaged across the six notional scenarios. Taken together the results indicate that complementing long-only factor-tilted portfolios with a short futures position leads to strategies with an attractive investment profile, resembling that of the academic factors. While returns across the board are lower than in the long-only format, and Sharpe ratios decay quickly with the size of assets deployed, the promise of this variant is related to its return stream being largely uncorrelated with the broader market and exhibiting less than half of the market's volatility. As such, the market-neutral variant would fit naturally in a portfolio context – not as a replacement of investors core equity allocation, but rather as a diversifying complement to it. Admittedly, the derivatives leg adds costs (driven primarily by the market impact component) so that scale considerations certainly apply, however, the clear diversification potential should support investment viability in the range of up to 100 mn, or about twice the median mutual fund size in Poland.

Figure 9. Average in-sample volatility and correlation estimates for market-neutral factor-tilted portfolios (2014-2024)



Note: volatility and correlation estimates averaged over six notional scenarios used in Table 4.

Figure 10. Cumulative net returns to a passive broad market fund against two momentum-based diversification strategies



Note: EPOL is the iShares MSCI Poland ETF benchmarked to the MSCI IMI Poland index; EPOL & Momentum (market neutral) is a monthly rebalanced portfolio allocating 50% to EPOL and 50% to a market-neutral version of the momentum factor as described in Table 4; EPOL & Momentum (long-only) is a monthly rebalanced portfolio allocating 50% to EPOL and 50% to a long-only version of momentum factor as described in Table 3; all returns in PLN terms.

As a case in point Figure 10 shows the cumulative returns (in PLN terms) to a strategy which starts with PLN 100 mn in assets and allocates 50% to the EPOL fund and 50% to the market-neutralized momentum factor with monthly rebalancing of positions and allocations. The results are benchmarked against a 100% allocation to EPOL and a 50-50 allocation to EPOL and the long-only momentum factor. Both versions of momentum allocations beat the EPOL benchmark, by about 120 bp in the case of the market-neutral version and a whopping 300 bp in the long-only

variant,[7] with a similar Sharpe ratio of 0.40 vs. 0.23 for EPOL. Interestingly, the two-fold improvement in investment efficiency relative to the EPOL is achieved through different means – a markedly higher return at comparable volatility (long-only variant) or a more modest return pickup but with markedly lower volatility (market-neutral).

5. Conclusions and practical implications

This paper studies the performance and investment viability of the main equity factors – value, momentum, quality and defensive (low volatility) – on the Polish market. The "academic" factors constructed as long-short portfolios are found to produce positive returns lowly (or negatively) correlated with the broad market, which reaffirms the case for incorporating them in portfolio construction, a point that aligns well with both practitioner and academic evidence from other markets. However, these optimistic results fall apart once factors are adjusted for the costs of trading, including commissions, spreads and market impact estimates, which are particularly high for the small and illiquid stocks often indiscriminately chosen by factor screens. Moreover, while costs directly drive implementation slippage, the practical inexistence of a market for shorting in Poland makes building and rebalancing a diversified portfolio of short positions, as required by the theoretical methodology, simply infeasible.

Still, it would be premature to discard factor screens altogether as useful portfolio construction tools. Polish factor premia originate from both legs but tend to be stronger on the long side. This leads to an important practical implication that style premia in Poland could potentially be harvested through long-only factor-tilted ("smart beta") portfolios, of the kind popularized already a decade a decade ago among US and European investors. The key to building such strategies on the Polish market – with its generally sub-par liquidity – requires thoughtful implementation focusing in particular on controlling turnover and constraining the traded universe to the most actively traded, large cap names, applying factor-based weights in assembling and rebalancing the portfolio. While these restrictions erode the strength of the factor signals to some extent, the loss appears to be more than offset by transaction cost savings. The backtests presented above show that such factor-tilted portfolios can work well both in a pure long-only format as well as complemented with a short position in WIG20 index futures which neutralizes much of the broad market exposure, limiting volatility and providing diversification benefits. However, some important caveats apply.

First, a recurring theme of the analysis has been the sensitivity of factor premia to scale, with the (simulated) deployment of greater assets generally depressing performance. Although the numbers should probably be treated with a grain of salt, it seems reasonable to conclude that given the current state of the market, any of the four factor-tilted strategies probably faces a capacity constraint of about PLN 1 bn, or roughly 4-5% of the total mutual fund assets invested in equities. These capacity constrains are likely to be relaxed somewhat as turnover in the underlying market picks up. In turn, greater equity market liquidity and broader adoption of factor strategies may depress factor premia, and the interaction of both effects warrants further study.

Second, in the interest of presenting a focused, streamlined narrative while mitigating the risk of data mining and overfitting, this paper considered only the four most popular systematic styles, expressed through the standard procedure using simple and easily available stock-level characteristics. One important drawback of such an analysis is that the estimated factor premia

[7] The comparison isn't exactly fair as the factor legs are gross of fees, while EPOL is net of a 60bp flat fee.

were probably distorted by unintended size and sector exposures which could be refined and purified in further studies.

Finally, while the current study draws attention to the importance of portfolio design choices in harvesting factor premia, it can hardly be regarded as an exhaustive analysis of the topic. More research is needed to understand how to optimize the trade-off between the costs of trading to align positions with fresh factor signals and the opportunity cost of not trading and running a more stale portfolio. An interesting aspect of portfolio design concerns also the question as to whether and how individual factor exposures should be mixed or integrated into core equity strategies so as not to dilute but strengthen each other's contribution. This in turn necessitates a better understanding of how different factors interact with each other in a portfolio context, especially once the unintended sector biases are removed.

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