Equity Factor Investing with Paris Aligned constraints

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Laurent Lagarde
is a head of Quant Equities at
BNP Paribas Asset Management in Paris, France.
laurent.p.lagard@bnpparibas.com, +33 (0)6 40 23 89 90

Raul Leote de Carvalho
is deputy head of the Quant Research Group at
BNP Paribas Asset Management in Paris, France.
raul.leotedecarvalho@bnpparibas.com, +33 (0)6 23 06 34 03

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Abstract

We provide insights into equity multifactor investing with Paris Aligned Benchmark (PAB) type constraints. Using an approach that minimises the impact of constraints on multifactor equity factor exposures, we investigate the effect of the minimum requirements and voluntary criteria from the European Union regulation for PABs. We explore various approaches to render the multifactor portfolio 'Paris Aligned'. These involve applying alignment constraints to the multifactor portfolio either with no other changes, or also replacing the strategy's benchmark with a PAB and/or reducing the investment universe for constituents of the PAB only. While minimum required constraints have a negligible impact on the information ratio and returns of the multifactor portfolio, this cannot be said of voluntary PAB constraints. We recommend that investors keep market cap-weighted benchmarks while imposing alignment constraints only to the multifactor portfolio. Changing to PABs does not seem to offer investors an advantage in terms of performance or alignment, while restricting the breadth of the universe reduces returns.

1. The proposed framework is useful for investigating the expected impact of PAB-type constraints on multifactor equity portfolios over short to medium-term investment horizons and can be repeated in the future to help investors make better investment decisions.
2. The minimum requirements of the EU regulation did not reduce the expected information ratio of equity multifactor portfolios, but some voluntary constraints appear to change the factor exposures in a way that reduces the expected returns of the portfolio.
3. Investors should not limit their investment universes to constituents of a PAB index since reducing the breadth decreases expected returns and is not a necessary condition to make sure that the multifactor portfolio aligns with PAB-type constraints.

Keywords: Factor investing, Equities, Net Zero, Paris Aligned, Smart Beta.

JEL Classification: G11; C61; D81

The Paris Agreement[1] is a legally binding international treaty on climate change adopted by 196 countries at the 21st Conference of the Parties of the United Nations Framework Convention on Climate Change (UNFCCC) in December 2015 and entered into force in November 2016. The agreement aims to strengthen the global response to climate change by keeping the rise in global temperatures this century to well below 2°C above pre-industrial levels and pursuing efforts to limit the increase to 1.5°C. The Paris Agreement also aims to increase the ability of countries to deal with the impact of climate change and provide financial flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development.

In May 2018, the European Commission amended its Benchmark Regulation (EU) 2016/1011, which defines the framework of benchmarks referenced in financial instruments, financial contracts or investment funds in the EU. The amended regulation (EU) 2020/1818[2] puts forward minimum standards for the methodology of the low-carbon indices EU Paris Aligned Benchmarks (PAB) and EU Climate Transition Benchmarks (CTB) based on the Paris Agreement commitments. This amended regulation is aligned with the objective of the Commission to reach net zero GHG emissions by 2050.

While the objective of both PAB and CTB indices is to limit global warming to well below 2°C, while seeking to limit the increase to 1.5°C, PAB and CTB methodologies vary in their level of ambition with CTBs being less constrained.

In this paper, we investigate the impact of introducing a PAB-type framework to manage multifactor equity strategies relying on traditional value, quality, momentum and low volatility factors to generate excess returns against a given equity benchmark.

Our approach to implementing PAB-type constraints in a multifactor portfolio is based on minimising their expected impact on the portfolio factor exposures. An optimiser is used to minimise changes in the exposures to the value, quality, momentum and low risk factors when constraints are added.

In our approach, we also assume that all impact on expected excess returns arises from changes in factor exposures induced by the PAB constraints, i.e., any impact of PAB constraints on the contributions of stock allocation to specific risk is not expected to generate alpha, at least not explicitly in our framework. In any case, if there is positive alpha associated with avoiding companies not aligned with a net zero pathway, that should still benefit our multifactor portfolio with PAB-type constraints. Minimising the impact of PAB-type constraints may not be optimal in such case, but to do better than that, we would need some estimation of the net zero premium with at least as much significance as the estimation of the premium of the value, quality, momentum and low volatility factors, which we do not have.

Designing actively managed strategies aligned with the EU framework is not as simple as designing PAB indices for passive replication. Indeed, there is no unique way to implement a PAB-type framework in actively managed portfolios such as those derived from a multifactor equity

[1] Paris Agreement to the United Nations Framework Convention on Climate Change, Dec. 12, 2015, T.I.A.S. No. 16-1104.

[2] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32020R1818

strategy. The regulation was designed for benchmark indices, not for actively managed portfolios. Simply replacing a market cap-weighted benchmark by a PAB is not sufficient to guarantee that the actively managed portfolios will remain aligned with the objectives of the regulation. It will always be necessary to impose constraints on the actively managed portfolios to make sure that they are also aligned with the minimum standards of the regulation.

In fact, replacing the benchmark by a PAB may not even be warranted if the investor plans to continue to use market cap-weighted indices as the ultimate benchmark of performance and risk. Thus, we can conceive several approaches to address this problem. First, we can consider either keeping the market cap-weighted index as the ultimate benchmark for risk and performance or switching to a PAB index. Second, irrespective of the chosen benchmark, we can consider either keeping the constituents of the market cap-weighted index as the investment universe or constraining the investment universe to only stocks in a PAB index. All these choices can make sense for as long as the multifactor portfolio is constrained to be aligned with the minimum standards of the regulation.

Our objective is to explore these different choices and assess their impact on the risk and returns of multi-factor portfolios. Typically, when comparing portfolio choices for systematic strategies that can be replicated over time, different choices are investigated by evaluating their simulated historical performance and risk. However, this is not easy when it comes to investigating choices related to the application of PAB-type approaches to multifactor investing. First, because of the lack of historical data, in particular the history of Scope 3 carbon emissions of companies[3]. Second, because the PAB minimum requirements are dynamic with constraints on the maximum carbon intensity of the portfolio falling over time. Such constraints would have been more relaxed in the past than they are going to be in the future. Finally, growing concerns about the carbon emissions of companies and societal pressures aimed at curbing them are relatively recent and unlikely to have had a significant impact in the distant past.

Instead, we chose to investigate the impact of PAB-type constraints on multifactor portfolio exposures to the value, quality, momentum and low risk factors constructed on a particular recent date. The proposed framework allows us to investigate the expected impact of PAB constraints on the shorter to medium-term future performance and risk of the multifactor portfolios and can be repeated and monitored periodically in the future. Thus, the results we discuss here are valid only for short to medium-term investment horizons. In fact, it would be pretentious to claim that we could have good enough visibility of how PAB-type constraints will impact a multifactor portfolio in the longer term. In the best-case scenario, companies reduce their carbon emissions and we will witness a smooth energy transition towards net zero by 2050 and beyond in line with limiting global

[3] The GHG Protocol Corporate Standard classifies a company's GHG emissions into three 'scopes'. Scope 1 emissions are direct emissions from owned or controlled sources. Scope 2 emissions are indirect emissions from the generation of purchased energy. Scope 3 emissions are all indirect emissions (not included in scope 2) that occur in the value chain of the reporting company, including both upstream and downstream emissions. Scope 3 was designed to help companies addressing their contribution to global carbon emissions, but not expected to play a role when comparing companies. Nevertheless, the EU PAB regulation does require the taking into account Scope 3 emissions for energy and mining sectors already today, and for transportation, construction, buildings, materials and industrial sectors not later than two years from inception and for all other sectors within four years.

warming to well below 2°C, even managing to stay close to a temperature increase of just about 1.5°C. In such a case, we can expect PAB-type constraints to have an increasingly smaller impact in the longer term. On the other hand, failure to keep the pace towards net zero would reflect the fact that an increasingly large number of companies is not aligning with net zero. Thus, we would expect a growing impact of PAB-type constraints in the future as the maximum allowed carbon intensity for the multifactor portfolio falls in line with the trajectory specified by the regulation.

Our analysis found that exclusions due decarbonisation and ESG constraints at present neither created any significant changes in the factor exposures of the multifactor portfolio nor reduced the information ratio of the portfolio significantly. In all, the minimum requirements of the EU regulation do not appear to significantly impact the expected returns. Only voluntary constraints proposed by the regulation seem to change the portfolio factor exposures enough to reduce the expected returns. These included a constraint on green revenues based on the assessment of a specific data provider, MSCI, and a constraint on limiting the exposure to companies with low carbon transition scores, based on the assessment of the same data provider.

Using MSCI market cap-weighted and PAB indices, we also found that investors should not restrict their investment universes to constituents of this PAB index since limiting the breadth reduces expected returns and is not a necessary condition to make sure that the multifactor portfolio fulfils PAB-type constraints. Changing the benchmark used to optimise the multi-factor portfolio from a traditional market cap-weighted benchmark to this PAB does not seem to have a significant impact on the absolute performance of the portfolio with PAB-type constraints. However, the MSCI World PAB index has negative exposures to the value and momentum factors relative to the MSCI World index, which suggest an expected underperformance relative to the MSCI World index. Switching to the MSCI World PAB index as the benchmark does not seem to offer any major advantage in terms of absolute performance. However, mainly because of the poorer expected performance of MSCI World PAB relative to MSCI World, the excess returns and information ratios of the multifactor strategy appear higher.

FRAMEWORK

In this section we describe the framework used to construct the multifactor portfolios and how constraints are imposed on it. We also show how we measure the factor exposures of the multifactor portfolio and how we can calculate the expected returns and tracking error risk from those factor exposures. At the end of the section, we provide the list of PAB-type constraints to be imposed, and we distinguish between the minimum required constraints and the voluntary constraints under the EU regulation on PAB.

Equity multifactor portfolios

The multifactor portfolios are constructed so as to target overweighting stocks with highest value, quality, momentum and low risk scores against a given benchmark such as the MSCI World index. The first step is to calculate the factor scores for each stock from the cross-sectional raw factor data. We used the factors proposed by Bellone et al. (2022), i.e. operating cash flow (net income for financials) to enterprise value, forward earnings to price and free cash flow yield as *value* factors; return on capital employed, free cash flow to assets and a measure of accruals (preferring low accruals) as *quality* factors; a measure of historical stock returns over the medium term and analysts' earnings revisions as *momentum* factors, and for *low risk*, we used only a measure of the historical volatility of returns of each stock. These factors were constructed with data from FactSet, Bloomberg, Worldscope and IBES for the constituents of MSCI indices.

The factors were constructed based on a z-scoring approach as proposed by Leote de Carvalho et al. (2017), not only avoiding sector biases, but also removing the exposure to market risk (beta) as well as controlling for the overall level of risk. These were found to be notable features that significantly enhance the risk-adjusted performance of multifactor strategies. Thus, on a given date, for *value*, we used a macro-sector-neutral long-short portfolio in which the weight of each stock is proportional to the equal-weighted combination of cross-sectional z-scores of the three value factors mentioned above. The beta is then neutralised ex-ante with the required dollar neutral position in the market cap index against cash. The leverage is sized, so that the ex-ante volatility is 2.5% at each monthly rebalancing.

The other factor styles, i.e., *quality*, *momentum* and *low risk*, are constructed using similarly robust macro-sector-neutral and beta-neutral long-short portfolios. Each of these portfolios also relies on a simple equally weighted combination of the respective factors mentioned above.

In exhibit 1, we show the long-term information ratios for each style of factors when applying this methodology to the constituents of the MSCI World index, calculated from a historical simulation from December 1995 through August 2022, which rebalances the long-short portfolios at the end of each month and uses monthly US dollar net total returns.

Exhibit 1

Long-term factor performances

	Information Ratio
Value	0.83
Quality	1.36
Momentum	0.60
Low vol	0.56

Notes: Based on net monthly returns in USD. December 1995 through August 2022. Calculated on October 2023. For illustration purposes only. Past performance is not indicative of future performance.
Source: MSCI, Worldscope, IBES, FactSet, Bloomberg, BNP Paribas Asset Management. Author's calculations.

In the absence of any constraints, we choose a multifactor portfolio that targets an allocation to these four style factors, so that their respective contribution to the tracking error is the same. This underlying multifactor portfolio is built with a tracking-error budget. Without constraints, the underlying multifactor portfolio would require implementing short stock positions. We apply constraints, e.g., long-only, using the robust portfolio optimisation approach adapted for multifactor equity portfolios proposed by Soupé et al. (2019). This is designed to minimise the impact of portfolio constraints on the risk-adjusted excess returns of multifactor equity portfolios by replicating the targeted factor exposures to the extent that the constraints allow. In that sense, this is almost equivalent to applying the tracking error minimisation approach proposed by Bolton, Kacperczyk and Samama (2022) not to the construction of a Paris-aligned benchmark portfolio, but to the construction of a multifactor portfolio instead. We find this approach better suited to the purpose than that proposed by Kolle et al. (2022) based on a two-step approach: first, a tracking error budget is used to bring the portfolio as close as possible to fulfilling the constraints required to keeping to a 1.5°C scenario; then a bigger tracking error budget is allocated to a factor overlay.

The fully invested long-only multifactor stock portfolios created using this approach tend to have a beta smaller than 1 relative to the benchmark index because of the exposure to the *low vol* factor. Liquid index futures can be used to hedge the beta back to 1 at each monthly rebalancing. This eliminates the return drag from the lower than 1 beta. Without this hedge, lower excess returns and higher tracking error should be expected in the medium to long term. In our calculations, we shall assume that a perfect beta hedge is possible, i.e., there is some combination of liquid index futures that perfectly replicates the market cap-weighted benchmark, which in our examples is the MSCI World index.

Impact of constraints on portfolio performance and risk

Here we give more details of the approach chosen to investigate the impact on the expected returns and tracking error of the multifactor portfolios optimised with and without PAB-type constraints and against PAB and non-PAB benchmarks.

The traditional approach used by quant managers of multifactor portfolios when it comes to addressing questions about the expected returns and risk of their strategies is to construct a historical simulation of what their strategies would have generated in the past. However, the lack of historical depth of relevant data, in particular for Scope 3 carbon emissions, makes it difficult to construct historical simulations without introducing strong approximations. Moreover, beyond the problem with the availability and quality of historical relevant data, such simulations would not consider other issues such as changes in regulations, the technological advances and shifts in market sentiment on decarbonising the economy or the need to decarbonise. Finally, the dynamic nature of the PAB constraints with regards to the decarbonisation pathway makes it almost irrelevant the use of traditional historical simulation methods.

We note that even the historical performance published by MSCI for the MSCI PAB World index is likely not representative of the future since, as explained by MSCI, prior to the May 2020 Semi-Annual Index Review (SAIR), the Weighted Average Carbon Emissions Intensity was calculated using Scope 1+2 emissions only (MSCI (2022)). Scope 3 was introduced only on that date. We note that Scope 3 emissions tend to be significantly higher than Scope 1+2 emissions for many companies, sometimes five to ten times larger. Adding Scope 3 can completely change portfolios.

Instead, we opted for a simpler approach which is informative of the expected impact of PAB-type constraints at least at present and for the short to medium term. This is based on investigating the impact of PAB-type constraints on the factor exposures of the multifactor portfolio on just one given recent date. In our analysis we assume that i) all of the impact of the PAB-type constraints on expected excess returns arises from changes in the factor exposures of the portfolio induced by these constraints and that ii) any impact of PAB constraints on the contributions of stock allocation to specific risk is not expected to generate alpha.

Below, we provide the analytic framework required to calculate the factor exposures of the multifactor portfolio, the expected returns and the expected tracking error relative to the portfolio benchmark.

Let $\boldsymbol{w}$ be the vector of stock weights of a benchmarked constrained portfolio, e.g., a multifactor portfolio, at a given date, and let $\boldsymbol{w}_I$ be the vector of stock weights in the benchmark portfolio, e.g., the portfolio from the MSCI World index, on the same date. The active weights of the constrained portfolio $\boldsymbol{w}$ relative to the benchmark are simply the difference $\boldsymbol{w} - \boldsymbol{w}_I$.

If $\boldsymbol{\beta}_I$ is the vector of stock betas relative to the benchmark portfolio on that same date, then the beta of the benchmarked constrained portfolio is $\beta = \boldsymbol{w}' \cdot \boldsymbol{\beta}_I$.

If $\boldsymbol{X}$ is a four-column matrix with the stock weights in the value, quality, momentum and low risk long-short style factor portfolios derived from their respective factor z-scores on that same date, then we can write the active weight of the multifactor portfolios $\boldsymbol{w} - \boldsymbol{w}_I$ as the sum of its exposure to the benchmark portfolio and the exposures to the long-short value, quality, momentum and low risk factor portfolios:

$$\boldsymbol{w} - \boldsymbol{w}_I = (\boldsymbol{w}' \cdot \beta_I - \boldsymbol{1})\boldsymbol{w}_I + \boldsymbol{X}' \cdot \boldsymbol{\gamma} + \boldsymbol{\epsilon} \tag{1}$$

where the factor exposures $\boldsymbol{\gamma}$ can be estimated from the ordinary least squares (OLS) cross-sectional regression**:**

$$\boldsymbol{\gamma} = (\boldsymbol{X}' \cdot \boldsymbol{X})^{-1} \cdot \boldsymbol{X}' \cdot (\boldsymbol{w} - \beta \boldsymbol{w}_I) \tag{2}$$

and with $\boldsymbol{\epsilon}$ a residual portfolio with stock weights neither correlated with the stock weights in the benchmark portfolio nor with the stock weights in the long-short style factor portfolios.

The beta hedged multifactor portfolio is then:

$$\boldsymbol{w} - (\boldsymbol{w}' \cdot \beta_I)\boldsymbol{w}_I = \boldsymbol{w} - \beta \boldsymbol{w}_I = \boldsymbol{X}' \cdot \boldsymbol{\gamma} + \boldsymbol{\epsilon} \tag{3}$$

With $\boldsymbol{\Sigma}$ the variance covariance matrix at the same date, we can calculate the volatility σ_I of the benchmark portfolio, which in our examples will be either the MSCI World index or the MSCI World PAB index, and σ_k the volatility of the each of the k unconstrained factor long-short portfolios $\boldsymbol{x}_k$ on the same date from:

$$\sigma_I^2 = \boldsymbol{w}_I' \cdot \boldsymbol{\Sigma} \cdot \boldsymbol{w}_I \tag{4}$$

$$\sigma_k^2 = \boldsymbol{x}_k' \cdot \boldsymbol{\Sigma} \cdot \boldsymbol{x}_k \tag{5}$$

We shall assume that the expected excess returns R_I^* of the benchmark portfolio can be estimated from the product of this volatility σ_I and the long-term Sharpe ratio, SR_I^*. Similarly, we assume that the expected returns R_k^* of the unconstrained long-short style factor portfolio k (with k = value, quality, momentum, low risk) can be estimated from the product of their respective volatility σ_k and their respective long-term information ratio, IR_k^*.

$$R_I^* = (SR_I^*)\sigma_I \tag{6}$$

$$R_k^* = (IR_k^*)\sigma_k \tag{7}$$

In our calculation, we used 0.38 as the long-term Sharpe ratio for the MSCI World index. For the factors, we used the long-term information ratios in exhibit 1. These are based on historical calculations using monthly net returns in US dollar terms from December 1995 through August 2022.

Based on these elements, the long-term expected return ER^* of the multifactor portfolio is then:

$$ER^* \simeq \beta R_I^* + \sum_{\boldsymbol{k}} \gamma_k R_k^* \tag{8}$$

The contribution from beta, i.e., the exposure to the MSCI World index, to the excess returns of the multifactor portfolio is:

$$(ER^* contrib)_I = \beta(IR_I^*)\sigma_I^* \tag{9}$$

while the contribution from the exposures of the style factor returns (value, quality, momentum and low risk) to the excess returns of the multifactor portfolio is:

$$(ER^* contrib)_k = \gamma_k(IR_k^*)\sigma_k^* \tag{10}$$

The tracking error of this multifactor portfolio is:

$$TE = \sqrt{(\boldsymbol{w} - \boldsymbol{w}_I)' \cdot \boldsymbol{\Sigma} \cdot (\boldsymbol{w} - \boldsymbol{w}_I)} \tag{11}$$

and its information ratio is:

$$IR^* = \frac{ER^*}{TE} \tag{12}$$

If the beta exposure of the multifactor portfolio is perfectly hedged with index futures, then the contribution from beta becomes zero and the excess return α^* of the hedged multifactor portfolio simplifies to:

$$\alpha^* \simeq ER^* - \beta R_I^* \simeq \sum_{\boldsymbol{k}} \gamma_k \, R_k^* \tag{13}$$

while the tracking error σ_α of the hedged portfolio is:

$$TE_{\boldsymbol{beta\ hedged\ portfolio}} = \sqrt{(\boldsymbol{w} - (\boldsymbol{1} - \beta)\boldsymbol{w}_I)' \cdot \boldsymbol{\Sigma} \cdot (\boldsymbol{w} - (\boldsymbol{1} - \beta)\boldsymbol{w}_I)} \tag{14}$$

Paris-aligned multifactor strategies

We shall now consider the different possible design choices for constructing Paris-aligned multifactor strategies which we investigate later.

First, we could just apply PAB-type constraints to the multifactor portfolio itself while managing the strategy against a traditional market cap-weighted index. Those constraints can impact the factor exposures of the portfolio and thus its ability to generate excess returns against the benchmark. This approach is suited to investors who use traditional market cap indices as benchmarks of performance and risk despite imposing constraints for aligning the portfolio with an EU PAB-type pathway to net zero.

A second approach is to replace the multifactor strategy benchmark with a PAB as the new reference for optimising the portfolio, measuring excess returns and tracking error risk. Such strategy is adequate for investors who simply find it easy to switch to PABs as the reference for measuring returns and risk. Nevertheless, changing the benchmark for investments must be accompanied by the application of PAB-type constraints if the strategy is to succeed in aligning portfolios with an EU PAB-type pathway to net zero.

Almost inevitably, investors taking the second approach will select one of the many commercially available PAB indices by index providers. Those indices tend to have more constraints and allocate to a smaller number of stocks than what is strictly required by the EU regulation. We can think of different ways of implementing this approach. For one, investors can replace the benchmark with a commercial PAB index such as the MSCI World PAB index and impose PAB-type constraints on the portfolio, but still allow the portfolio to invest in non-benchmark stocks in the original market cap-weighted index that are not excluded under the EU regulation. Another possibility is to impose the additional constraint on the portfolio requiring it to invest only in the constituents in the chosen commercial PAB index, reducing the investment universe available to the portfolio. We shall investigate these possible combinations and the consequences they may have on expected performance and risk. By using the MSCI World PAB index as the commercial benchmark, we shall also investigate the impact of the additional constraints that are used to construct this index and that are not strictly imposed by the EU regulation.

Multifactor portfolio constraints

In this section, we describe the Paris alignment constraints we shall impose on the multifactor portfolio. They include a mix of minimum requirements, similar to those imposed by the EU regulation, and additional constraints based on voluntary criteria proposed by the EU regulation and used by MSCI in its families of PAB indices.

These constraints use datasets by MSCI for environmental, social and governance (ESG) company scores, corporate carbon emission intensity (CO2I) aligned with the calculation requirements imposed by the EU regulation which require Scope 1+2+3 emissions and a normalisation by enterprise value including cash (EVIC), green company revenues (GR), low carbon transition company scores (LCTS) and company credible carbon-reduction targets (CCRT).

Green revenue is calculated by MSCI as the cumulative revenue in percent from six clean technology themes: i) alternative energy, ii) energy efficiency, iii) sustainable water, iv) green building, v) pollution prevention and vi) sustainable agriculture. MSCI Low Carbon Transition Scores are based on a multi-dimensional risks and opportunities assessment. This considers both the predominant and secondary risks a company faces. It is industry agnostic and represents an absolute assessment of a company's position vis-à-vis the transition. Finally, the MSCI Credible Carbon-Reduction Targets assess companies on i) corporate decarbonisation pledges, ii) decarbonisation commitments, iii) climate risk engagement and iv) the reporting of portfolio emissions pursuant to frameworks such as the Task Force on Climate-related Financial Disclosures (TCFD).

PAB-type minimum requirements

The following constraints are designed to be aligned with the EU regulation for PAB:

- CO2I: maximum all scopes (Scopes 1+2+3) corporate carbon emission intensity (CO2I) normalised by EVIC[4] for the multifactor portfolio, given by the minimum between 50% of the MSCI World index CO2I on 30 November 2022 and a pro-rata 7% reduction year-on-year[5] of the CO2I on 30 November 2022 relative to the CO2I or the MSCI World index on 31 December 2021, and which results in a maximum CO2I of 141.24 t/EUR million EVIC

[4] Enterprise Value Including Cash is defined as the sum of the market capitalisation of ordinary shares at fiscal year-end, the market capitalisation of preferred shares at fiscal year-end, and the book value of total debt and minorities' interests. No deductions of cash or cash equivalents are made to avoid the possibility of negative enterprise values

[5] A trajectory under which the average GHG intensity is reduced by at least 7% year-on-year with the targets calculated in a geometric progression from the base year. It is important to note that the EU regulation requires that if the average EVIC of the benchmark changed in the last calendar year, each constituent's EVIC is adjusted by dividing it by an enterprise value inflation adjustment factor = (average EVIC of benchmark at the end of calendar year) / (average EVIC of the benchmark at the end of previous calendar year)

- HIS: no reduction in exposure to high-impact sectors (HIS)[6] in the multifactor portfolio relative to the MSCI World index while using the NACE industry classification defined by the European Commission (2008)
- Exclusion of companies:
  - related to controversial weapons;
  - related to the cultivation and production of tobacco;
  - that derive 1 % or more of revenues from exploration, mining, extraction, distribution or refining of hard coal and lignite; or 10 % or more from the exploration, extraction, distribution or refining of oil fuels; or 50 % or more from the exploration, extraction, manufacturing, or distribution of gaseous fuels; or 50 % or more from electricity generation with GHG intensity higher than 100 g CO_2 e/kWh,
  - found in violation of the United Nations Global Compact principles or the Organisation for Co-operation Economic and Development (OECD) Guidelines for Multinational Enterprises.

Voluntary constraints beyond PAB-type minimum requirements

This is a set of additional voluntary constraints imposed on the multifactor portfolio based on proposals in the EU PAB regulation. They aim at taking the portfolio one step further in terms of aligning with a net zero pathway by considering other criteria than just carbon intensity and exclusions. Here we chose to impose:

- ESG: based on a company's ESG aggregate scores, exclusion of the decile with worst ranked companies in each sector using the GICS level 1 sector definitions; we require that the weighted average ESG score of the multifactor portfolio to be equal to or greater than that for the MSCI World index,
- GR: constrain the weighted average of a company's green revenues (GR) in the portfolio so that it is equal to or greater than that for the MSCI World PAB index,
- LCTS: constrain the weighted average low-carbon transition score of companies in the portfolio so that it is equal to or greater than that in the MSCI World PAB index,
- CCRT: constrain the weight of companies with credible carbon-reduction targets in the portfolio so that it is equal to or greater than the weight of such companies in the MSCI World PAB index.

RESULTS

In this section, we show the results for the different designs of multifactor portfolios using PAB-type constraints and either the MSCI World index or the MSCI World PAB index as their benchmark, investing in either the constituents of the MSCI World index or those from the MSCI World PAB index.

[6] Section A: Agriculture, Forestry and Fishing; Section B: Mining and Quarrying; Section C: Manufacturing, Section D: Electricity, Gas, Steam and Air Conditioning Supply; Section E: Water Supply, Sewerage, Waste Management and Remediation Activities; Section F: Construction; Section G: Wholesale and Retail Trade; Section H: Transportation and Storage; Section L: Real Estate Activities.

The impact of constraints on the expected returns and risk of the portfolios is calculated using the framework described in the section above (equations (1) through (14)). The portfolios were constructed with factor and market data as of 30 November 2022.

Once the multifactor portfolios were constructed while applying the set of constraints and using the different designed choices, the exposures $\boldsymbol{\gamma}$ of the constrained portfolios to the value, quality, momentum and low risk factors were calculated from equation (2). The contribution from the exposures of the factor returns was calculated using these exposures $\boldsymbol{\gamma}$ and the factor information ratios in exhibit 1 in equation (10). The contribution of beta hedging of the portfolios was calculated from equation (9) and using the Sharpe ratio of 0.38 for the MSCI World index, estimated over the same period as the information ratios of the factors in exhibit 1. The return of the beta-hedged portfolio is given by equation (13) and arises only from the factor contributions, i.e., the same result as from equation (10). The tracking error risk of the portfolio without beta hedging is given by equation (11), whereas for the beta-hedged portfolio, it is calculated from equation (14).

Simulations against the MSCI World index as benchmark

In this section, we show the results for multifactor portfolios benchmarked against the MSCI World index on 30 November 2022. The excess returns and tracking error are measured relative to the MSCI World index. The investment universe is based on the constituents of the MSCI World index on this date.

We first compare the factor exposures for the fully invested multifactor portfolio i) without any constraints, ii) with a long-only constraint and exclusions and iii) with a long-only constraint, exclusions, and all PAB-type constraints (minimum and voluntary).

The first two cases allow us to estimate the expected impact of the basic and often unavoidable constraints in multifactor portfolios. The last case allows us to investigate the impact of adding the PAB constraints. As shown in exhibit 2, the unconstrained portfolio has similar exposures to the factors and a beta equal to 1. The small differences from an exact equal exposure to the factors arise from the impact of their small correlations with each other on the contribution to the tracking error of the portfolio.

The main impact of the long-only constraint is to change the factor exposures relative to what is targeted in the unconstrained portfolio. An overweight of *value* relative to the other factors results from the fact that this factor was easier to implement in a long-only portfolios because the underlying long-short factor portfolio was less leveraged. This has been the case in recent years. The long-only constraint reduces the beta to 0.9 because of the investment in low-risk stocks without allowing for leverage. With a beta of 0.9, hedging the beta requires a position of 10% in futures replicating the MSCI World index returns.

Finally, in exhibit 2, we can see that the PAB constraints reduce the factor exposures, but their risk budgets are aligned with what we found for the long-only portfolio without PAB constraints.

Exhibit 2

Exposures of multifactor porftolios versus MSCI World index

Optimization benchmark: MSCI World index	Unconstrained	Long-only & exclusions	
Investment universe: MSCI World index		without PAB constraints	with PAB constraints
Beta vs MSCI World	1.00	0.90	0.90
Value	0.30	0.56	0.52
Quality	0.33	0.26	0.19
Momentum	0.32	0.26	0.18
Low vol	0.43	0.32	0.20

Notes: For illustration purposes only. Calculated on October 2023.
Sources: MSCI, Worldscope, IBES, FactSet, Bloomberg, BNP Paribas Asset Management. Author's calculations.

We can now calculate the expected returns and tracking error risk of these portfolios and the impact of not hedging the beta from the results in exhibit 2 as explained above. We show these results in exhibit 3. The unconstrained portfolio has an information ratio of 1.13. The multifactor portfolio with a long-only constraint and exclusions has a similar information ratio provided the beta is hedged with futures. The contribution of the futures to the performance is 62bp. If the hedge with futures is removed, then because the beta of the constrained fully invested portfolio is just 0.9, the performance is 62bp lower, the tracking error is much higher because of the beta being not equal to 1, and the final information ratio is much smaller. Hedging beta is thus important for the final performance and a lower tracking error as expected.

Exhibit 3

Performance and risk of multifactor portfolios versus MSCI World index

Optimization benchmark: MSCI World index Investment universe: MSCI World index	Excess Return	Tracking Error	Information Ratio	Beta hedge contribution to excess reurns
unconstrained & beta = 1	3.78%	3.35%	1.13	-
long-only & exclusions	3.31%	4.07%	0.81	-
long-only & exclusions & beta = 1	3.93%	3.35%	1.17	0.62%
long-only & exclusions & beta = 1 & PAB constraints	3.11%	3.41%	0.91	0.59%

Notes: Based on net monthly returns in USD. Calculated on October 2023.
For illustration purposes only. Pas performance is not indicative of future performance.
Sources: MSCI, Worldscope, IBES, FactSet, Bloomberg, BNP Paribas Asset Management. Author's calculations.

In exhibit 4, we show the sustainable objectives that must be fulfilled by the multifactor long-only portfolio with PAB constraints and the sustainable characteristics of multifactor portfolios optimised with and without PAB constraints, comparing them to those found in the MSCI World index. This shows the extent of the deviation of the sustainable characteristics of the different portfolios relative to the targeted objectives. The impact of futures to hedge beta – a form of risk management – is not considered in measuring these exposures. This is in line with the current directives of the EU for handling futures in calculating the sustainable characteristics of a portfolio. The ESG scores and LCTS vary between 1 for worst performers and 10 for best. Green revenues vary between 0% and 100%. HCI and CCTR are either 1 or 0 for each stock. The HCI and CCTR figures in exhibit 4 represent the sum of the weight of stocks in the portfolio that pass the criteria, i.e., that are 1.

Exhibit 4

Sustainable characteristics of the portfolios

Optimization benchmark: MSCI World index Investment universe: MSCI World index	Sustainable objectives		multifactor portfolios* PAB constraints without	multifactor portfolios* PAB constraints with	MSCI World index
ESG	minimum	6.94	7.47	7.23	6.94
CO2I (t/EUR million EVIC)	maximum	141.24	141.95	474.84	457.22
HCI	minimum	62.7%	63.0%	63.2%	62.7%
GR	minimum	11.2%	11.3%	3.0%	11.2%
LCTS	minimum	6.74	6.78	6.11	6.74
CCRT	minimum	39.3%	40.7%	39.1%	39.3%
Exclusions	maximum	0.0%	0.0%	0.0%	9.9%

*** long-only & exclusions & beta = 1**

Notes: Calculated on October 2022. For illustration purposes only.
Sources: MSCI, Worldscope, IBES, FactSet, Bloomberg, BNP Paribas Asset Management. Author's calculations.

With a significantly higher all-scope corporate carbon emission intensity (CO2I) than required, even higher than that of the MSCI World index, the starting long-only multifactor portfolio without PAB constraints did not pass all the targeted objectives. It also had a lower exposure to green revenues than required. Other constraints were either fulfilled or almost fulfilled. By construction, the PAB-constrained long-only portfolio meets all the targets. Finally, we can see that the stocks in the exclusion list have a 9.9% weight in the MSCI World index.

Exhibit 5

Performance and risk of multifactor portfolios* versus MSCI World index

Optimization benchmark: MSCI World index Investment universe: MSCI World index		Excess Return	Tracking Error	Information Ratio	Beta hedge contribution to excess returns
multifactor portfolio*		3.93%	3.35%	1.17	0.62%
minimum PAB requirements	**+ CO2I**	3.80%	3.30%	1.15	0.61%
	+ CO2I + HCI	3.74%	3.26%	1.15	0.59%
voluntary PAB constraints	**+ CO2I + HCI + GR**	3.28%	3.34%	0.98	0.60%
	+ CO2I + HCI + GR +LCTS	3.11%	3.41%	0.91	0.59%
	+ CO2I + HCI + GR +LCTS + CCTR + ESG	3.11%	3.41%	0.91	0.59%

*** long-only & exclusions & beta = 1**

Notes: Based on net monthly returns in USD. Calculated on October 2023.
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Sources: MSCI, Worldscope, IBES, FactSet, Bloomberg, BNP Paribas Asset Management. Author's calculations.

We now investigate the impact of each individual PAB constraint. In exhibit 5, we show the impact of adding each of the PAB constraints on the information ratio, excess returns and tracking error risk of the portfolio, including both the minimum requirements and the voluntary constraints. From the results, we can see that in aggregate, the constraints reduce the excess return by 82bp, from 3.93% to 3.11%, and the tracking error from 3.35% to 3.41%. This results in a reduction of the information ratio from 1.17 to 0.91, provided the beta is hedged to 1. Not hedging the beta will reduce the expected excess return by an additional 59bp p.a., which is about the same as the cost of not hedging the beta in the equivalent long-only multifactor portfolio without the PAB constraints, i.e., 62bp p.a. The constraint on green revenues reduces the expected excess return by 46bp p.a. The constraint on low-carbon transition scores (LCTS) reduces the expected return by 17bp p.a. while the constraint on all-scope carbon intensity has a negative impact of 13bp p.a. on expected returns.

While the minimum required PAB constraints have a relatively small impact on the information ratio of the portfolio, the same cannot be said of the two voluntary PAB constraints. Constraining the portfolio on the basis of green revenues and low carbon transition scores has a significant impact, not only lowering excess returns but even the information ratio. We can see that the cost of not hedging the beta would have been similar for all portfolios because they all have the same level of beta – about 0.9. Other constraints do not seem to have any significant incremental impact relative to the constraints already implemented.

In exhibit 6, we provide additional information on the long-only multifactor portfolios with and without PAB constraints. We show that the PAB constraints reduce the number of stocks in the long-only portfolio from 221 to 150. We investigate the liquidity of the portfolios indicating how much of a USD 2 billion portfolio could have been traded in one day if we were to cap the amount traded of each stock at a maximum 20% of its average daily volume. We can see that the PAB-constrained portfolio is slightly more liquid than the long-only portfolio without PAB constraints. PAB constraints do not seem to create liquidity issues in this example despite reducing the number of stocks in the multifactor portfolio.

Exhibit 6

Number of constituents and liquidity of the multifactor portfolios*

Optimization benchmark:	**MSCI World index**	**Number of constituents**	**Cumulated weight**
Investment universe:	**MSCI World index**	**> 1bp**	**executed within 1 day**
PAB constraints:	**Without**	221	73%
	With	150	82%

*** long-only & exclusions**

Notes: Calculated on October 2023. For illustration purposes only.
Sources: MSCI, Worldscope, IBES, FactSet, Bloomberg, BNP Paribas Asset Management. Author's calculations.

Constraining the investment universe

We now investigate the impact of reducing the size of the investment universe by allowing the multifactor portfolio to invest only in stocks from the MSCI World PAB index while still retaining the MSCI World index as the benchmark for performance and risk measurement.

In exhibit 7, we show the impact on the factor exposures from changing the investment universe. We considered the two long-only multifactor portfolios benchmarked against the MSCI World index using either the MSCI World index as the investment universe or the MSCI World PAB index and generated the results using the same framework as before. We can see that constraining the investment universe to the stocks in the MSCI PAB index reduces the factor exposures further and increases the beta of the long-only portfolio slightly.

Exhibit 7

Exposures of multifactor portolios*

Optimization benchmark	Investment universe	
MSCI World index	MSCI World index	MSCI World PAB index
Beta vs MSCI World	0.90	0.92
Value	0.52	0.41
Quality	0.19	0.17
Momentum	0.18	0.13
Low vol	0.20	0.16

* long-only & exclusions & PAB constraints

Notes: Calculated on October 2023. For illustration purposes only.
Sources: MSCI, Worldscope, IBES, FactSet, Bloomberg, BNP Paribas Asset Management. Author's calculations.

In exhibit 8, we show the results for the performance and risk of these portfolios. We considered that the beta of the portfolios relative to the MSCI World index is hedged to 1 and, as before, we include the contribution of doing so in the results. The smaller factor exposures shown in exhibit 7 explain the smaller excess returns resulting from constraining the investment universe. Reducing the investment universe to constituents of the MSCI World PAB index reduces the excess returns from 3.11% to 2.49% and the information ratio from 0.91 to 0.73. The negative impact of this constraint on performance is thus about 62bp p.a. The slightly higher beta explains the smaller contribution of just 47bp p.a. arising from hedging the beta.

Exhibit 8

Performance and risk of multifactor portfolios* versus MSCI World index

Optimization benchmark:	MSCI World index	Excess Return	Tracking Error	Information Ratio	Beta hedge contribution to excess reurns
Investment universe:	MSCI World index	3.11%	3.41%	0.91	0.59%
	MSCI World PAB index	2.49%	3.42%	0.73	0.47%

* long-only & exclusions & PAB constraints & beta = 1

Notes: Based on net monthly returns in USD. Calculated on October 2023.
For illustration purposes only. Past performance is not indicative of future performance.
Sources: MSCI, Worldscope, IBES, FactSet, Bloomberg, BNP Paribas Asset Management. Author's calculations.

Changing to a PAB benchmark

When changing to a PAB benchmark, it is useful to know the expected performance and tracking error risk of the new PAB benchmark relative to the one it replaces. We can answer this question in a similar way by investigating the factor exposures of the PAB index relative to the fully invested market cap-weighted index. In exhibit 9, we show exactly this, using the same framework as described and used in the previous sections for the multifactor portfolios.

As shown in exhibit 9, the beta of the active weights of the MSCI World PAB index relative to the MSCI World index is close to neutral. However, we find negative *value* and *momentum* exposures relative to the MSCI World index which should act as a drag on performance. Using a similar approach to the one we used to calculate expected returns for the multifactor portfolios, we estimate that the MSCI World PAB index[7] could underperform the MSCI World index by 63bp p.a. as a result of the negative exposures to *value* and *momentum*. We also estimate a tracking error of 2.81% for the MSCI World PAB index relative to the MSCI World index on the same date. In all, in view of these factor exposures, we conclude that the MSCI World PAB index does not appear to provide an efficient strategy to implementing Paris Aligned Benchmark-type constraints, at least at present and taking into account the underperformance it derives from the negative exposures to the *value* and *momentum* factors.

Exhibit 9

Index factor exposures

	MSCI World PAB index versus MSCI World index
Beta	1.03
Value	-0.22
Quality	0.01
Momentum	-0.11
Low vol	0.04

Notes: Calculated on October 2023. For illustration purposes only.
Sources: MSCI, Worldscope, IBES, FactSet, Bloomberg, BNP Paribas Asset Management. Author's calculations.

We now consider the impact of changing the benchmark altogether. Here, we replace the MSCI World index with the MSCI World PAB index as the benchmark for portfolio construction, performance and risk. We are interested in the impact that such a choice will have on the performance of the PAB-constrained multifactor portfolio.

In exhibit 10, we show the factor exposures and beta of two long-only portfolios optimised relative to the MSCI World PAB index as their benchmark and applying PAB constraints. The only difference between these portfolios is that the first can still invest in stocks in the MSCI World index, while the second can invest only in stocks in the MSCI World PAB index. The betas relative to the MSCI World PAB index are just slightly smaller than those against the MSCI World index. The factor exposures are more balanced than in the case of the multifactor portfolios optimised against the MSCI World index shown in exhibit 7, with a smaller exposure to the *value* factor and a bigger exposure to *low vol*. Much like before, in exhibit 7 for the optimisation against the MSCI World index, the exposures to the factors when optimising against the MSCI World PAB index are diluted further when the investment universe is reduced to the constituents of the latter only.

[7] We note that the methodology behind the MSCI World PAB index changed significantly in the May 2020 Semi-Annual Index Review with the addition of Scope 3. We would thus be careful not to extrapolate conclusions taken from the analysis of the index performance prior to that date.

Exhibit 10

Exposures of multifactor portolios*

Optimization benchmark	Investment universe	
MSCI World PAB index	MSCI World index	MSCI World PAB index
Beta vs MSCI World	0.87	0.90
Beta vs MSCI World PAB	0.84	0.86
Value	0.36	0.28
Quality	0.22	0.21
Momentum	0.15	0.14
Low vol	0.33	0.27

*** long-only & exclusions & PAB constraints**

Notes: Calculated on October 2023. For illustration purposes only.
Sources: MSCI, Worldscope, IBES, FactSet, Bloomberg, BNP Paribas Asset Management. Author's calculations.

In exhibit 11, we show the excess returns and tracking error relative to the MSCI World PAB index of the two long-only portfolios with PAB constraints in exhibit 10. The returns against the MSCI World PAB index of these portfolios optimised against the MSCI World PAB index are larger than the excess returns against the MSCI World index in exhibit 8 for the portfolios optimised against the MSCI World index.

Exhibit 11

Performance and risk of multifactor portfolios* versus MSCI World PAB index

Optimization benchmark:	MSCI World PAB index	Excess Return	Tracking Error	Information Ratio	Beta hedge contribution to excess reurns
Investment universe:	MSCI World index	3.68%	3.64%	1.01	0.87%
	MSCI World PAB index	3.27%	3.64%	0.90	0.74%

*** long-only & exclusions & PAB constraints & beta = 1**

Notes: Based on net monthly returns in USD. Calculated on October 2023.
For illustration purposes only. Past performance is not indicative of future performance.
Sources: MSCI, Worldscope, IBES, FactSet, Bloomberg, BNP Paribas Asset Management. Author's calculations.

However, knowing that the MSCI World PAB index is expected to underperform the MSCI World index by 62bp due to the negative exposures to the *value* and *momentum* factors in exhibit 9, what can we expect in terms of excess returns against the MSCI World index for the multifactor portfolios optimised against the MSCI PAB index? The results in exhibit 12 show exactly this and can be compared directly with those in exhibit 8. In fact, we find that there is no meaningful change in expected returns from changing the benchmark from the MSCI World index to the MSCI World PAB index, at least for as long as the beta is hedged. The higher excess returns against the MSCI World PAB index turn out to be compensated for by the outperformance of the MSCI World against the MSCI World PAB index. Therefore, changing the benchmark appears to have a negligible impact in absolute terms.

However, the contribution to excess return from hedging increases because of the lower beta. If hedging the beta is not possible, keeping the MSCI World index as the benchmark is clearly preferable from the point of view of performance. If hedging the beta is possible, switching to the MSCI World PAB index as the benchmark has little impact on the portfolio return. Still, even when benchmarking against the MSCI World PAB index, we still expect a better performance when allowing for the broader investment universe.

Exhibit 12

Performance and risk of multifactor portfolios* versus MSCI World index

Optimization benchmark:	MSCI World PAB index	Excess Return	Tracking Error	Information Ratio	Beta hedge contribution to excess reurns
Investment universe:	MSCI World index	2.95%	3.45%	0.86	0.77%
	MSCI World PAB index	2.51%	3.43%	0.73	0.61%

* long-only & exclusions & PAB constraints & beta = 1

Notes: Based on net monthly returns in USD. Calculated on October 2023.
For illustration purposes only. Past performance is not indicative of future performance.
Sources: MSCI, Worldscope, IBES, FactSet, Bloomberg, BNP Paribas Asset Management. Author's calculations.

CONCLUSIONS

In this paper, we propose different approaches to introducing a Paris Aligned Benchmark-type framework in the management of multifactor equity strategies. We use the MSCI World index and the MSCI World PAB index as possible benchmarks and their respective constituents as possible investment universes. The approaches impose constraints derived from the EU PAB regulation on the portfolio. Those constraints are consistent with either the minimum requirements or the voluntary constraints proposed by the EU regulation for PAB.

We investigate the impact of constraints on the multifactor portfolios by measuring the deviation in their exposures to the *value*, *quality*, *momentum* and *low volatility* factors relative to those targeted. We propose the framework to derive the impact on excess returns and tracking error risk from those deviations to factor exposures. We carry out the analysis on a given recent date and argue that historical simulations will be of limited value because of the lack of historical data and the low pertinence of the results in face of the dynamic nature of the PAB-type constraints and the relevance of past company carbon emissions. We believe that our framework is useful for investigating the expected impact over short to medium-term investment horizons and can be repeated in the future to help investors take the best investment decisions.

Overall, we find that the minimum requirements of the EU PAB regulation have almost no impact on the information ratio of the multifactor portfolio and have a relatively small impact on the expected return of the portfolios. However, some of the voluntary constraints imposed had a negative impact on expected returns, namely the constraints limiting the exposure to stocks with less green revenues and with low-carbon transition scores. From our analysis, we also find that it is more efficient to use the traditional MSCI World index as the investment universe than the MSCI World PAB index, even when the benchmark for tracking error and excess return is changed from the MSCI World to the MSCI World PAB.

Our analysis suggests that the MSCI World PAB index is not the most efficient portfolio for investing in equity markets while imposing PAB-type constraints. In the absence of a null net zero risk premium, the negative relative exposure to *value* and *momentum* relative to the MSCI World index are expected to create a performance drag relative to the latter. However, we also find that there is no significant impact on the expected returns of the PAB-constrained multifactor portfolios arising from the change of benchmark, provided the beta of the portfolio can be hedged and the portfolio can invest in stocks from the MSCI World index. Investors can just expect higher excess returns from portfolios with PAB-type constraints when measured and optimised against the MSCI World PAB than when measured and optimised against the MSCI World, provided they do not constrain the investment universe. If the beta cannot be hedged, keeping the MSCI World index as the benchmark is certainly preferable because the negative impact on excess returns from not hedging is smaller. Constraining the investment universe to constituents from the MSCI World PAB index only will reduce expected returns in all cases.

Finally, the most important takeaway from this paper is the proposed methodology for assessing the impact of constraints, which could be used to investigate the impact of following other approaches to net zero investing, e.g. the framework based on net achieving, aligned, aligning stock screens as proposed by the Paris Aligned Investment Initiative (PAII (2021)) from the Institutional Investors Group on Climate Change.

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