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Introduction

I am delighted to introduce the latest Scientific Portfolio special issue of the EDHEC Research Insights supplement to Investment & Pensions Europe (IPE), which aims to provide institutional investors with an academic research perspective on the most relevant issues in the industry today.

We first look at the potential for digitalised *self-indexing* to help institutional asset owners fulfil their fiduciary responsibilities. In effect, our recent survey reveals that fewer than half have the capacity to fully analyse their risk exposures, while more than 90% expect the passive investment industry to be headed towards further customisation capabilities to account for ESG and climate objectives.

At a time when sustainable finance is likely facing an identity crisis, we highlight the interdependence of the main building blocks that sustainable investors ought to consider – themes, levers (exclusions, allocation, engagement) and data, and propose a practical classification of sustainable investments via four families of consistent strategies.

We aim to specifically help portfolio managers set greenhouse gas (GHG) emissions reduction targets and avoid 'greenwashing' by introducing a new attribution methodology for the GHG emissions of equity portfolios. Our approach is inspired by environmental economics and breaks down (historically and/or cross-sectionally) emissions into five major drivers.

We then show that long-term conditional simulations can be an important ingredient of an equity investment process. In effect, we define a series of meaningful macroeconomic regimes that significantly impact equity returns and empirically observe that the behaviour of equity portfolios can be efficiently extrapolated in different regimes over multiple economic cycles.

To assist investors who are subject to a strict risk budget, we examine the benefits of factor-based diversification of active risk to stabilise the tracking error relative to a cap-weighted benchmark. Our approach, inspired by the Equal Risk Contribution concept, is applied to the US equity ETF universe where we find supportive empirical evidence.

Finally, we contribute to a European debate on the consistency of equity funds reported as sustainable. We analyse the possible trade-off faced by asset managers between a sustainability objective and financial risk constraints and show that the incremental exclusion of stocks deemed controversial would have no material impact on the risk profile of the funds, especially if a simple optimisation procedure is applied to reallocate portfolios.

We hope that the articles in the supplement will prove useful, informative, and insightful. We wish you an enjoyable read and extend our warmest thanks to IPE for their collaboration on the supplement.

Shahyar Safaee, Deputy CEO and Business Development Director, Scientific Portfolio (an EDHEC Venture)

The perceived advantages of self-indexing for institutional equity investors

Benjamin Herzog, CEO, Scientific Portfolio; **Jenna Jones**, Senior Product Specialist, Scientific Portfolio; **Shahyar Safaee**, Deputy CEO, Business Development Director, Scientific Portfolio

Institutional asset owners increasingly seek customised strategies to take their ESG and climate preferences into consideration, independently designing customised indices to meet their needs.

They can build on available direct indexing technology, in particular, the digitalised portfolio analysis and construction functionalities on offer.

However, there is a tradeoff between finance and ESG objectives; our recent survey of institutional asset owners reveals that less than half have the capacity to fully analyse their risk exposures. That said, more than 90% anticipate improvements in the customisation capabilities of the passive investment industry.

These findings highlight the significant potential for the use of self-indexing as a solution to help institutional asset owners fulfil their fiduciary responsibilities.

Institutional asset owners increasingly seek to customise index-linked strategies in order to take their ESG and climate preferences into consideration.[1]

This trend away from cap-weighted benchmarks does, however, bring forth challenges for asset owners in fulfilling their fiduciary duties. To address these issues, a new self-indexing approach can provide investors with the tools to fully control the index design process and independently monitor the direct and indirect impacts of customisation decisions.

Introduction: The long road towards full customisation

The history of equity indexing can be described as a long road from consensus-based investing towards full customisation. One-size-fits-all solutions have given way to more personalised offerings that incorporate investor views and preferences. In particular, the past decade has heralded the arrival of non-cap-weighted indices integrating environment, social or governance (ESG) criteria. Even though these are often derived from broad CW indices, their composition and/or weighting schemes use non-financial stock-level characteristics and may sometimes display fairly strong deviations from broad indices. This may be due to sector allocation, since some sectors are often strongly under-represented (eg, oil and gas and, more generally, energy and climate indices), or to stock-level allocation, since some stocks may be under-weighted or excluded based on ESG criteria. For example, recent research carried out by EDHEC Business School as part of the Scientific Portfolio project has shown that complying with a 'do no harm' (DNH) exclusion policy with respect to each of the 17 Sustainable Development Goals (SDGs) defined by the United Nations leads to an exclusion of almost 40% of the stocks in the world developed markets universe. Given the absence of either an academic or an industry-wide consensus with respect to the construction of ESG portfolios, the design of an ESG benchmark (and more generally the field of ESG investing) is more representative of an institutional investor's preferences and notably the objectives defined by its governing body or managing board, than the result of the index provider's internal research. Consequently, the value added by the main ESG index providers is ultimately more about access to new data than the imposition of a particular portfolio construction method.

Clearly, the predominance of investor preferences in index design has had considerable consequences on index offerings. However, the alleged full customisation of indices is ultimately a commercial offering from index providers who understandably aim to showcase the quality of their product. This can manifest through various means, whether it be via the selection of the most favourable metrics supporting the affirmed objectives of the index, the choice of the backtesting period or, more generally, the adoption of a framework to perform an index risk

1 This article is an abridged version of the white paper: B. Herzog, J. Jones and S. Safaee (2023). The Perceived Advantages of Self-Indexing for Institutional Equity Investors. EDHEC Scientific Portfolio, June. Access the paper here: https://scientificportfolio.com/pdfs/The Perceived Advantages of Self-Indexing for Institutional Investors.pdf

analysis. Therefore, although the investor indeed expresses customisation choices, the implementation of these choices has remained the responsibility of the index provider. But this status quo is evolving; the concept of self-indexing, already popular among retail and high-net-worth individual investors through direct indexing offerings, is beginning to emerge in institutional investment management.

Institutional self-indexing

Institutional investors have a focus on fiduciary issues. As a reminder, fiduciaries are required to act prudently and to diversify their investment portfolio in order to minimise the risk of large losses. Therefore, the capacity for them to integrate, analyse and select the risks associated with their index-based investments is essential. Moreover, when it comes to ESG objectives, most institutional investors are not content with off-the-shelf offerings and wish to be able to express their preferences in a very precise way, either in the form of proprietary customised investment lists that are aligned with ESG objectives (eg, SDGs, climate change mitigation, climate risk), or aligned with their engagement strategy.

Based on the above considerations and to conclude, the foundations of institutional self-indexing are:

- the ability to address investors' need to 'self-implement' high levels of customisation in various dimensions (financial, ESG risk, ESG impact), and
- the ability to holistically 'self-analyse' the proposed investment strategies independently from any commercial consideration, and therefore the capacity to control not only the design of the index but also the consequences of any design decision.

EDHEC Self-Indexing Survey: Motivations and Expectations of Institutional Asset Owners

EDHEC conducted a survey on self-indexing with the aim of identifying and highlighting the potential advantages of self-indexing for institutional equity investors that are pursuing specific objectives and facing certain constraints. Responses were gathered during April-May 2023 from 45 institutional asset owners in North America and Europe, collectively overseeing an estimated total AUM of $2.5trn, which can be deemed to be a reasonable representation of the global institutional asset owner universe.[2]

Below we summarise some of the key responses and the implications these hold for the industry. The full survey and its responses are given in the Appendix.

Factor risk analysis capabilities

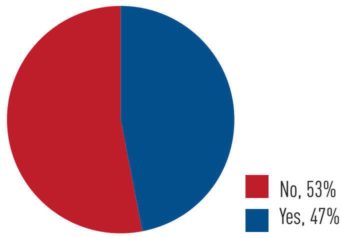
QUESTION 1 – CAN YOU ANALYSE YOUR OWN RISK EXPOSURE?

Fewer than half (21 out of 45) of the respondents stated that they had the capacity to analyse the risk factors to which their current equity index-linked mandates or funds are exposed, as shown in figure 1. To emphasise the importance of analysing a portfolio's risk factor exposures, we present an illustrative example in figure 2. In this scenario, two providers offer ETFs with 'value' mentioned in the name. Evaluating these funds through the same lens allows for a standardised comparison that can uncover unexpected exposures and highlight potential inconsistencies between a fund's name and its risk profile.

Despite both funds being categorised as value-focused, their 'value' exposures differ significantly. Value fund 2 demonstrates negligible exposure to the value risk factor, whereas value fund 1 exhibits a notably positive exposure to it. The construction rules of an index-linked fund and, to a greater extent, the name of the fund, are not always transparent indicators of its actual exposures; therefore, using a single risk model will help determine the actual exposures (whether absolute or relative) and alert investors when a customisation may introduce new unwanted exposures.

1. Can you analyse your own risk exposure?

Do you have your own capacity to analyse the risk factors to which your current equity index-linked mandates or funds are exposed?

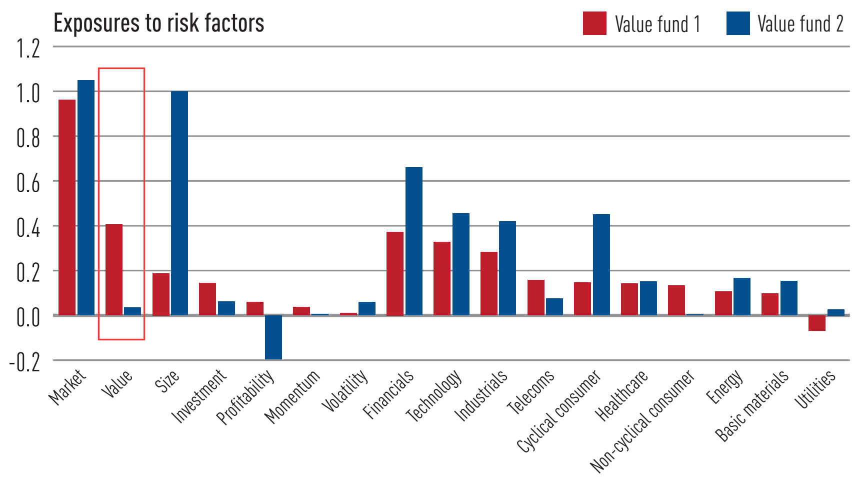


Finance versus ESG tradeoffs

QUESTION 3 – IN PRINCIPLE, COULD YOUR FINANCIAL *AND* ESG OBJECTIVES BE PRIORITISED?

In view of the significant development in ESG customisations, it was interesting to investigate investors' capabilities in reconciling financial and non-financial objectives. Indeed, optimising a portfolio solely based on financial objectives without considering the ESG impact could potentially result in a worsened ESG position for the portfolio. At the same time, optimising a portfolio based on an ESG objective may have financial implications. In other words, there is a tradeoff between making a financial or ESG decision, so prioritisation is necessary. According to the survey (see

2. Risk factor exposures for two funds labelled with 'value' listed in their names

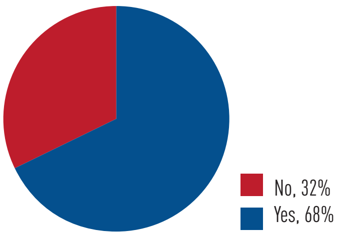


Source and full details: Herzog, Jones and Safaee (2023).
https://scientificportfolio.com/pdfs/The Perceived Advantages of Self-Indexing for Institutional Investors.pdf

2 Percentages (%) of respondents reported hereafter for a given question refer to the proportion of the subset of participants that answered the question.

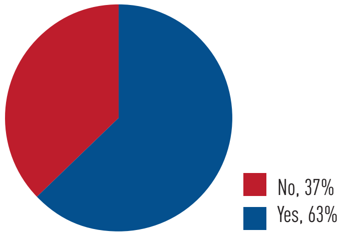
3. In principle, could your financial *and* ESG objectives be prioritised?

In principle, could your financial and ESG objectives be prioritised: for example, maximising the impact on one or more ESG dimensions while respecting a factor exposure or a tracking error constraint, or maximising exposure to one or more financial risk factors while respecting an ESG constraint?



4. Do you occasionally request customisation of a reference index?

Do you occasionally request a customisation of the chosen reference index to reflect personal preferences?



5. ... and, if so, how do you check that's what you have got?

If you occasionally request a customisation of the chosen reference index to reflect personal preferences, how do you verify that the customisation objectives have been met?

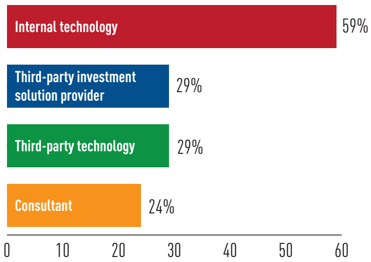


figure 3), 68% of respondents (19 out of 28) stated that they could prioritise their financial and ESG objectives, such as maximising the impact on one or more ESG dimensions while respecting a factor exposure or tracking error constraint or maximising exposure to one or more financial risk factors while respecting an ESG constraint.

A common tradeoff faced by equity investors is the empirical relationship (documented by academic research on US large cap stocks) between value, profitability and carbon intensity. Indeed, an unconstrained customisation aimed at mitigating the carbon intensity of a portfolio would likely generate a short value tilt and a long profitability tilt, two exposures that have historically been reported in the design of climate impact indices. These exposures happened to be sources of market outperformance and then subsequently market underperformance in the past three years, thus illustrating the benefits that self-indexing could bring by integrating both ESG and financial considerations in a single independent analysis.

Relationship with providers of customised investment solutions

QUESTION 5 – DO YOU OCCASIONALLY REQUEST CUSTOMISATION OF A REFERENCE INDEX?

... AND, IF SO, HOW DO YOU CHECK THAT'S WHAT YOU HAVE GOT?

QUESTION 7: DO YOUR SOLUTION PROVIDERS *OFFER* TO CUSTOMISE YOUR REPORTS?

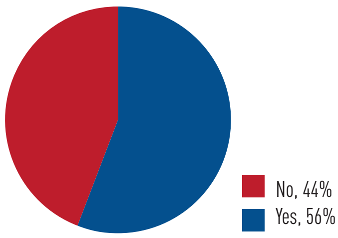
...AND HOW DO YOU MANAGE THINGS IF THEY *DON'T*?

Among the survey respondents (see figure 4), 63% (17 out of 27) indicated that they occasionally seek to customise a chosen reference index to align with their personal preferences. For those individuals that did seek customisations, they were asked to select all methods they use to verify whether the customisation objectives were achieved. The results show that 59% (see figure 5) of respondents (10 out of 17) utilise internal technology, while 29% (five out of 17) rely on third-party technology. Furthermore, 29% (five out of 17) selected a third-party investment solution provider, and 24% (four out of 17) reported using a consultant to assist in the customisation process. As per figure 6, only 56% (15 out of 27) of respondents' investor solutions providers offered to adapt to the respondents' financial and ESG reporting formats. Among the remaining 44% (12 out of 27) who were not offered this service, they responded with the various approaches they currently employ to manage the resulting discrepancies. Specifically, as shown in figure 7, 67% (eight out of 12) use a manual process, 33% (four out of 12) utilise internal technology, 8% (one out of 12) rely on third-party technology, and 25% (three out of 12) chose 'other' as their preferred approach.

It is important that institutional asset owners exercising a fiduciary responsibility verify that their customisation objectives have been met, although in the most holistic sense. This means verifying that intended consequences are indeed observed (eg, improvement of targeted metrics), but also looking for unintended

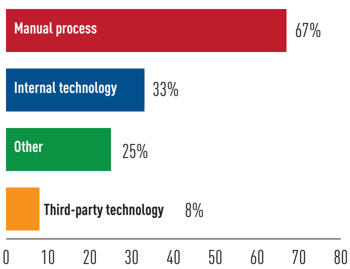
6. Do your solution providers *offer* to customise your reports?

Do your investment solutions providers offer to adapt to your financial and ESG reporting formats?



7. ...and how do you manage things if they *don't*?

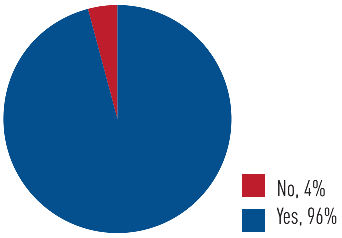
If your investment solutions providers do not offer to adapt to your financial and ESG reporting formats, how do you currently manage the resulting discrepancies?



consequences (eg, unexpected deterioration of other metrics). Indeed, the backtesting results published by an

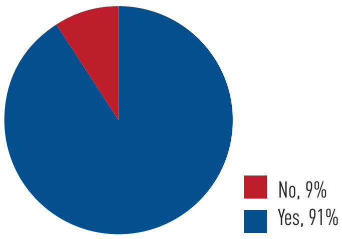
8. Is the institutional passive investment industry headed towards further customisation?

Do you think the institutional passive investment industry is headed towards further customisation capabilities?



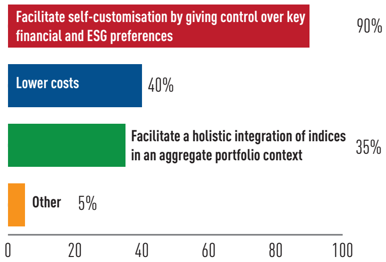
9. Will digital services such as direct indexing play a role in institutional passive equity investing?

Do you think digital services such as direct indexing could play a role in the next evolutions of institutional passive equity investing?



10. ... and, if so, what elements are of interest?

If you think digital services such as direct indexing could play a role in the next evolutions of institutional passive equity investing, do you expect institutional investors to be interested in direct indexing for its ability to:



investment solutions provider are only a regulatory minimum and not a comprehensive risk analysis. It is therefore critical for the investor to be able to 'go beyond' a historical sample (generally selected by the solutions provider) and test the robustness of a customised strategy in various market environments. This may be done simply by selecting a different historical period for the analysis (which requires the ability to perform long-dated historical simulations) or by going one step further and generating hypothetical scenarios (which requires the ability to perform out-of-sample simulations).

Anticipated evolution of the passive investment industry

QUESTION 8 – IS THE INSTITUTIONAL PASSIVE INVESTMENT INDUSTRY HEADED TOWARDS FURTHER CUSTOMISATION?

QUESTION 9: WILL DIGITAL SERVICES SUCH AS DIRECT INDEXING PLAY A ROLE IN INSTITUTIONAL PASSIVE EQUITY INVESTING?

... AND, IF SO, WHAT ELEMENTS ARE OF INTEREST?

According to the survey findings (see figure 8), 96% of respondents (26 out of 27) hold the belief that the institutional passive investment industry is headed toward further customisation capabilities. Moreover, as per figure 9, a substantial proportion (91%, or 21 out of 23) of participants acknowledged the potential role of customised digital services, such as direct indexing, in achieving this customisation. When respondents were asked about the primary reasons driving institutional asset owners' interest in self-indexing, they were provided with the opportunity to select multiple choices. As shown in figure 10, the primary reason, selected by 90% of participants (18 out of 20), was the desire for self-customisation, allowing investors to have control over their key financial and ESG preferences. Additionally, 35% (seven out of 20) of respondents recognised the potential of self-indexing in facilitating the holistic integration of indices within an aggregate portfolio context. Lower costs were also identified as a significant driver, with 40% of respondents (eight out of 20) emphasising the potential cost advantages associated with self-indexing. These findings highlight the growing appetite for a customisation service akin to self-indexing among institutional asset owners.

Conclusion

Institutional investors regularly seek exposure to passive index-linked strategies that deviate from market capitalisation-weighted benchmarks by targeting specific characteristics that are more aligned with their preferences. This new industry paradigm of full customisation, largely caused by ESG and climate indices, is nevertheless not conducive to an appropriate fulfilment of fiduciary duties. An instruction communicated to an index provider to customise with respect to a given objective does not guarantee that the objective will be met. Additionally, verification based on the sole observation of metrics or characteristics specifically designed to monitor the achievement of the objective cannot be considered exhaustive. Only a holistic and independent analysis capable of uncovering and highlighting possibly unintended exposures will provide assurance to an asset owner that prudent risk management has been implemented.

The new concept of self-indexing addresses this issue directly and suggests investors want the analytical tools that will enable them to fully control the index design process and monitor (at any time) the direct and indirect impacts of any customisation decisions. Institutional asset owners are in need of solutions that enhance their risk management processes and self-indexing could benefit from the digitalisation that facilitated the adoption of direct indexing.

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Appendix – EDHEC Self-Indexing Survey

The following presents a comprehensive overview of the survey, including the complete set of questions and corresponding results. The survey encompasses three types of questions: yes/no questions – [Y/N], multiple-choice questions – [MCQ] and a free-text response – [Free Text].

Section A: Taking the existing allocation into account

1. Do you have your own capacity to analyse the risk factors to which your current equity index-linked mandates or funds are exposed? [Y/N] – yes: 47%, no: 53%
   - If 'yes', do you also have the capacity to check how your index-linked mandates or funds contribute to your factor risk exposures at an aggregate portfolio level? [Y/N] – yes: 86%, no: 14%
   - If 'no', would it be important for you to acquire such capacity? [Y/N] – yes: 54%, no: 46%

Section B: Reconciling financial and non-financial objectives

2. As part of your index selection or mandate design process, are you capable of simulating the financial consequences (eg, absolute or relative risks, exposure to risk factors, extreme risks) of ESG choices and conversely, the ESG impacts (eg, exposure to climate or SDG issues) of your financial choices? [Y/N] – yes: 47%, no: 53%
   - If 'yes', are you conducting the simulation analysis internally? [Y/N] – yes: 69%, no: 31%
   - If 'no', are you in a position to independently assess the information and the analyses presented by third party investment solution providers (ie, asset managers or index providers)? [Y/N] – yes: 60%, no: 40%
   - If 'no', would it be important for you to be able to do this independently of the third party providing the investment solution? [Y/N] – yes: 71%, no: 29%

3. In principle, could your financial and ESG objectives be prioritised – for example, maximising the impact on one or more ESG dimensions while respecting a factor exposure or a tracking error constraint, or maximising exposure to one or more financial risk factors while respecting an ESG constraint? [Y/N] – yes: 68%, no: 32%
   - If 'yes', would it be important for you to be able to test different prioritisation schemes independently of third-party investment solution providers? [Y/N] – yes: 74%, no: 26%

Section C: Your relationship with investment solution providers

4. Do you personally select the reference index for the funds or mandates that you use? [Y/N] – yes: 71%, no: 29%
   - If 'no', do you delegate this task to: i) a consultant, ii) an asset manager, iii) an index provider, iv) other [Free Text]? [MCQ] – consultant: 50%, asset manager: 38%, index provider: 25%, other: 0%

5. Do you occasionally request a customisation of the chosen reference index to reflect personal preferences? [Y/N] – yes: 63%, no: 37%
   - If 'yes', is the customisation of your mandate carried out by i) sponsoring the launch of a custom version of the index, ii) implementing a customised mandate under a tracking error constraint with respect to the original index, iii) other [Free Text]? [MCQ] – sponsoring the launch of a custom version of the index: 53%, implementing a customised mandate under a tracking error constraint with respect to the original index: 47%, other: 18%
   - If 'yes', how do you verify that the customisation objectives have been met: i) internal technology, ii) third-party technology, iii) consultant, iv) third-party investment solution provider, v) other [Free Text]? [MCQ] – internal technology: 59%, third-party technology: 29%, third-party investment solution provider: 29%, consultant: 24%, other: 6%
   - If 'yes', are you satisfied with the level of explanation and transparency you are getting from your investment solution provider regarding the financial or ESG consequences of the requested customisation? [Y/N] – yes: 59%, no: 41%

6. Do you use an ESG reference dataset that is independent of your investment solutions providers? [Y/N] – yes: 48%, no: 52%

7. Do your investment solutions providers offer to adapt to your financial and ESG reporting formats? [Y/N] – yes: 56%, no: 44%
   - If 'no', how do you currently manage the resulting discrepancies: i) internal technology, ii) third-party technology, iii) manual process, iv) other [Free Text]? [MCQ] – manual process: 67%, internal technology: 33%, third-party technology: 8%, other: 25%

Section D: The passive investment economy

8. Do you think the institutional passive investment industry is headed towards further customisation capabilities? [Y/N] – yes: 96%, no: 4%
   - If 'yes', over which aspects would it be important for institutional investors to regain control? [Free Text] – portfolio and index construction, tracking of performance versus customised benchmarks, better knowledge of long-term consequences, ESG compliance, economic thought instead of ESG overload, exclusions and risk factor exposures, risk management.

9. Do you think digital services such as direct indexing could play a role in the next evolutions of institutional passive equity investing? [Y/N] – yes: 91%, no: 9%
   - If 'yes', do you expect institutional investors to be interested in direct indexing for its ability to i) lower costs, ii) facilitate self-customisation by giving control over key financial and ESG preferences, iii) facilitate a holistic integration of indices in an aggregate portfolio context, iv) other [Free Text]? [MCQ] – facilitate self-customisation by giving control over key financial and ESG preferences: 90%, lower costs: 40%, facilitate a holistic integration of indices in an aggregate portfolio context: 35%, other: 5%

Institutional equity portfolios: how can asset owners build coherent sustainable strategies?

Vincent Bouchet, ESG Director, Scientific Portfolio; **Shahyar Safaee**, Deputy CEO, Business Development Director, Scientific Portfolio

Sustainable finance is facing a double 'identity crisis'. On the one hand, society is increasingly denouncing greenwashing and questioning the impact of sustainable finance. On the other hand, practitioners are divided on the (double) materiality definition and the levers that have an extra-financial impact.

This article aims to help institutional investors faced with these questions when building sustainable portfolios. In this summary, we highlight the interdependence of the main building blocks that investors ought to consider – themes, levers (exclusions, allocation, engagement) and data. We then propose a classification of sustainable investments and four families of coherent sustainable investment strategies that combine themes, levers and data in a consistent way.

Introduction

'Sustainable' finance has clearly accelerated since the early 2010s. Global 'sustainable investment' reportedly[1] represented about 38% of all professionally managed assets in 2022, while the number of financial institutions adhering to the Principles for Responsible Investment has risen from fewer than 250 in 2006 to 3,404 in 2021. Despite this acceleration, sustainable finance is currently facing a double 'identity crisis'[2]: a crisis of credibility and an internal crisis caused by divergent definitions and principles.

While regulations aimed at sustainable activities and investing have developed, no consensus prevails on the definition of a sustainable investment. Concerns over the risk of 'financial greenwashing' have increased, leading to investigations into financial institutions suspected of greenwashing practices.

Concerns about whether sustainable investing has an effect on the 'real' economy have increased. For instance, the trend in global greenhouse gas (GHG) emissions is far from being compatible with the targets set in the Paris Agreement (IPCC [2022]). The financial sector cannot be held solely responsible for this development, but IPCC (2022) points out a lack of financing on climate mitigation and adaptation solutions on one side, and "persistently high levels of both public and private fossil fuel-related financing" on the other. The UN Sustainable Development Goals (SDGs) established in 2015 have been popular among financial institutions for measuring extra-financial impact (GIIN [2020]), but in 2023, the UN reported that "progress on more than 50 per cent of targets of the SDGs is weak and insufficient; on 30 per cent, it has stalled or gone into reverse"[3].From a macroeconomic perspective, it is legitimate to doubt the effects of finance on sustainable development.

The second component of the identity crisis involves the relationship between financial and non-financial materiality and the most effective strategies for impacting the real economy. Should extra-financial information be assessed solely for its financial impact, or should the environmental and societal effects of corporations or investment portfolios also be considered? Despite ongoing debate, it is recognised that non-financial performance does not necessarily conflict with financial performance, with studies showing that sustainable investing performs similarly to traditional investing (Atz et al [2023]). However, supporters of the double materiality approach still grapple with determining the most effective strategies for managing and influencing portfolio constituents' impact on the environment and society. Is engagement more effective than exclusion? Is it better to optimise a portfolio's carbon intensity or its average ESG score? Despite extensive academic research on the links between financial and extra-financial performance, the extra-financial impact of sustainable finance remains overlooked (Kölbel et al [2020]; Sjöström [2020]).

In a recent research paper (see Bouchet and Safaee [2023]) aimed to assist institutional investors faced with these questions when building and managing sustainable portfolios, we first examine the building blocks investors need to consider – themes, levers and data. We emphasise that choices within these blocks are interdependent. We then propose a classification of sustainable

1 Global Sustainable Investment Alliance (GSIA).
2 The 'identity crisis' of sustainable finance expression is from Chiu et al (2022).
3 The Sustainable Development Goals Report 2023 – Special edition. Available at: https://unstats.un.org/sdgs/report/2023/The-Sustainable-Development-Goals-Report-2023.pdf

investments and different levels of ambition regarding extra-financial impact. We finally demonstrate that diverse pragmatic approaches are viable, leading to the construction of four coherent families of sustainable investment strategies.

Reviewing choices to build a sustainable equity portfolio

Building a sustainable portfolio requires making choices about themes, levers and data. This section aims to summarise trends among practitioners and insights from academic research on these decisions.

Themes: from local 'ESG' to global 'SDG'

The origins of sustainable investing can be traced back to Jewish, Christian and Islamic traditions and to early funds such as the Pioneer Fund. In the 1960s, it took on a political role, notably in opposition to the Vietnam War. However, the concept of incorporating extra-financial considerations in investment decisions faced criticism, epitomised by Milton Friedman's assertion that profit maximisation is a business's sole responsibility. Environmental disasters in the 1970s and 1980s spurred further development, aligning with the rise of corporate responsibility. An examination of corporate social responsibility in the early 1970s reveals a shift towards addressing internal issues caused by company activities.

Climate change emerged as a catalyst for sustainable investing from the mid-2000s, emphasising global challenges that necessitate collaboration across sectors. Since 2015, the UN's SDGs have provided a shared framework for addressing both global environmental and social challenges but require adaptation for financial institutions. Sustainable investors must collaborate with various stakeholders and align with frameworks like the SDGs to effectively address current global challenges.

Levers to influence companies

Achieving SDGs requires behavioural changes from companies. Sustainable investors face the challenge of identifying effective levers to instigate these changes. Although there's no consensus on categorising these levers, they can be simplified into three types: exclusion, allocation and engagement. Exclusion involves removing certain stocks from the portfolio, influencing the selection process. Allocation entails applying a weighting scheme to selected stocks. Engagement involves establishing relationships with companies and stakeholders. To address the fiduciary duty of some sustainable investors, a careful weaving of selection and allocation decisions may be required (see the section below on Incorporating financial risk considerations for more details).

Defining an investment universe: exclusion

Exclusion, the oldest sustainable finance practice, remains popular but its growth is slowing. Current exclusions mostly target climate change, notably with fossil fuel divestment. Regulations like the EU's climate benchmark rules prescribe exclusion criteria, yet institutions and regulators vary widely in metrics and thresholds, complicating implementation and assessment. Exclusion policies depend heavily on data coverage and quality, with asset managers often creating exception rules.

From an academic perspective, exclusion has received extensive study, with research suggesting that divestment can reduce a company's capital offer, raising its cost of equity capital and lowering its share price. However, empirical studies on exclusion's impact on asset prices and portfolio performance produce conflicting results, necessitating tailored analyses for effective risk-constrained alignment. The impact of exclusion on companies' extra-financial performance remains underexplored, with debates persisting on its effectiveness compared to engagement strategies.

Exclusion is relevant in several scenarios: addressing widely condemned non-sustainable activities, serving as a last resort when engagement fails, and aligning with investors' moral imperatives or resource constraints. Understanding exclusion's implications beyond financial metrics requires consideration of both direct and indirect impacts.

Building a portfolio: allocation

Allocation rules related to sustainable issues – ie, reweighting securities without excluding any firms from the portfolio – can support two types of objectives. In the first, the aim is to maximise sustainable metrics like ESG scores, carbon intensity, or average sustainable revenues, primarily limited in effect to impacting the cost of capital. The second type of objective may ensure a minimum exposure to certain market segments, either based on neutrality criteria that require no less exposure to climate sectors, or sustainability criteria, such as a minimum allocation to companies providing climate solutions.

Another approach views allocation as an intermediary step between engagement and exclusion, where incentivising managers to take corrective actions through tilting strategies might be more effective than divestment. This strategy relies on the assumption that managers are incentivised to reform if they know investors will reinforce their position, thereby supporting share prices.

So, when is the allocation lever relevant? While holdings-based allocation can impact the cost of capital, its indirect impacts are limited compared to exclusion, which also has a binary and public nature. However, in certain scenarios, tilting and incentivisation strategies can serve as intermediary steps before exclusion when combined with engagement efforts. Allocation remains crucial for ensuring portfolio exposure to desired sustainability objectives, with segment-based strategic allocation approaches preferred over holdings-based maximisation approaches for robustness. This allows for stock-level optimisation to be entirely dedicated to the management of traditional financial risks, while subject to sustainability constraints (see below).

Being an active shareholder: engagement

Climate change has become a central focus of engagement efforts, with two emerging trends: the development of specific ESG votes like 'Say on Climate' resolutions and collective investor initiatives like Climate Action 100+. Engagement extends beyond dialogue with companies to 'field building', ie, engagement with peers and regulators, acknowledging broader influences on corporate behaviour.

From an empirical perspective, the question of the effectiveness of engagement in changing corporate behaviour remains overlooked (Sjöström [2020]). Kölbel et al (2020) review five studies showing success rates ranging from 18% to 60% in triggering reforms that enhance company activities. Barko et al (2022) report significant improvements in average ESG ratings of firms following engagement, while Flammer et al (2021) find increased voluntary disclosure of climate change risks after shareholder activism, though this does not necessarily imply a reduction in greenhouse gas emissions.

In conclusion, engagement is relevant when investors are looking to create behaviour change, particularly in transitioning non-sustainable activities to sustainable ones. However, it requires significant time and resources and should prioritise specific themes and companies. Its effectiveness is enhanced when accompanied by a clear exclusion threat, shared with other investors, and extended beyond direct relations with companies (field building).

Primary and secondary ESG data to build and monitor a portfolio
A BNP Paribas survey found that 71% of institutional investors identified "incomplete and inconsistent data" as the most significant barrier to increasing adoption of sustainable investment.[4] However, these apparent obstacles may vary depending on whether the data in question is primary, directly describing a company's state and activities, or secondary metrics derived from primary data (figure 1).

1. Examples of ESG data according to their characteristics

	Standardised data		Non-standardised data	
	Modelled	**Measured***	**Modelled**	**Measured***
Primary data				
Monetary metrics related to revenues, consumption or investments		Revenues from sustainable activities	Revenues related to SDGs	
Physical metrics related to consumption and production	Carbon emissions Scope 1	Water consumption	Biodiversity footprint	Number of electric cars produced
Qualitative data related to sustainable strategy, controversies		Climate strategy		Biodiversity commitments
Secondary data				
Aggregated metrics			Scores, alignment temperature	
Extended responsibility metrics	Carbon emissions Scope 2 and 3		Avoided emissions	
Prospective metrics	Science-based targets		Alignment temperature	

* Can also be modelled by data providers when the data has not been measured by a company

Primary data
Primary data for sustainable investing is increasingly standardised, with metrics aligned with reporting requirements for both non-financial and financial companies, particularly emphasising climate mitigation. Additionally, the involvement of new institutions is providing access to more public data, such as Urgewald's Global Coal Exit List and the Finance Exclusion Tracker Initiative's aggregated exclusion list. Technological advances such as web scraping and text analysis are enabling the generation of alternative ESG data, particularly for real-time monitoring of controversies. These developments have resulted in more reliable ESG primary data, making it preferable for defining exclusion criteria or sustainable investment segments requiring binary decisions.

Secondary data
ESG ratings are widely used but contentious due to significant divergences among providers. These discrepancies persist at both the company and fund levels, indicating a lack of convergence. Research suggests that the main source of divergence lies in the measurement of ESG attributes rather than differences in scope or weight. Moreover, there's a 'halo effect' where high scores in one attribute correlate with high scores across others. Empirical studies reveal that ESG scores correlate with voluntary disclosures but not with compliance records or carbon emissions levels. Additionally, sustainable mutual funds, despite higher ESG scores, have shown worse compliance records. Critics argue that ESG scores often aim to estimate financially material risks rather than reflect sustainability performance accurately.

Alongside ESG scores, secondary metrics have emerged, particularly in climate change mitigation, but their results vary widely and pose challenges in comparison due to differing methodologies and potential black box effects. Despite these challenges, secondary metrics offer valuable insights and opportunities for enhanced dialogue with companies.

Pragmatic ambitions for coherent sustainable strategies

The choices when building a sustainable portfolio – themes, levers and data – are not necessarily exclusive (eg, engagement and exclusion), but are interdependent (eg, data quality and themes). Then how should they be combined? In this section, we discuss possible definitions of sustainable investment and possible degrees of extra-financial impact. We show that pragmatic answers to these questions are possible, and that these answers lead to four types of consistent combinations of themes, levers and data.

Defining sustainable investments
The EU Commission has indicated that financial institutions should define "sustainable investment", emphasising three criteria: avoiding harm to environmental or social objectives, contributing to these objectives, and adhering to good governance standards. While the EU Commission introduced the notion of sustainable *investment*, the concept of sustainable *development* is not a new one, and its history may help an institutional investor to define a sustainable investment.

Travelling back in time to an enlightened period
The seminal 1987 Brundtland report defines sustainable development as meeting the present needs without compromising the ability of future generations to meet their own needs. However, historical evidence suggests that the concept of sustainability dates back to the 18th century. Carl von Carlowitz, overseeing silver mining in Germany in 1713, advocated forest conservation to sustain the wood supply chain. A few decades later, in the spring of 1789, Thomas Jefferson suggested to his friend Lafayette that he consider the rights of future generations while drafting the French Declaration of the Rights of Man and of the Citizen. Indeed, Jefferson supposed it "to be self-evident that the earth belongs in usufruct to the living". In sustainable finance terms, the original definition of sustainable development is therefore closer to a 'do no harm' injunction than a call to 'positive contribution'.

The first type of sustainable investment for equity portfolios aligns with the original concept of sustainable development, focusing on companies that conduct their business without causing significant harm to the planet or people. To implement this, the specific nature of 'harm' must be defined, considering both activities (what is produced) and behaviour (how the company produces). This can be achieved through frameworks like the EU taxonomy's do no significant harm (DNSH) criteria or the SDG framework. Primary data such as revenue distribution, consumption and production metrics, and controversies are preferred for screening such investments.

A second type of sustainable investment is related to investments in companies with 'positive contributions', ie, companies that, through their core

4 Incomplete and inconsistent data was followed by greenwashing (61%) and the difficulty of reconciling ESG investing with fiduciary duties (53%), according to the BNP Paribas Global ESG Survey 2023, available at: https://securities.cib.bnpparibas/global-esg-survey-2023/global-esg-survey-2023-report/

activities (not behaviour), provide solutions to achieve one of several SDGs. To qualify for this second type of sustainable investment, companies must meet a minimum threshold of positive contribution (from some, but not necessarily all activities) while managing negative impacts (from all activities and behaviour, consistent with the 'do no harm' type defined above). The SDI Asset Owner Platform, for instance, sets criteria for defining such investments. Primary data like revenues and production metrics should be favoured for screening positive companies, as they offer a clearer picture of the actual activities conducted, unlike secondary metrics such as scores, which are known to focus more on behaviour and which may obscure the distinction between positive and negative contributions by netting them out.

Setting and monitoring pragmatic ambitions for change

A portfolio and its manager's contribution to change is central to building a consistent sustainable strategy. What level of extra-financial effect can investors target and how can they demonstrate it?

Targeting change, from alignment to impact

Although the effects of sustainable practices on corporate behaviour remain overall overlooked by the academic literature, empirical studies on engagement show small yet significant changes. These findings support a theoretical model of change based on three levers: exclusion, allocation and corporate/stakeholder engagement. However, the extent of change depends on resource allocation, both organisational (eg, human resources for engagement, data availability) and financial (eg, impact of exclusion or allocation choices on risk). Strategies can range from *alignment*, where no specific change is expected but holdings align with values, to *impact*, where explicit improvements in behaviour or activities are targeted.

Demonstrating extra-financial impact requires understanding causality, not just observing changes in performance. Given the quantity of factors that can influence final *outcomes*, we suggest that institutional investors should set targets on, manage and report on what they have control over, ie, '*outputs*', to ensure the *consistency* of their strategy (figure 2).

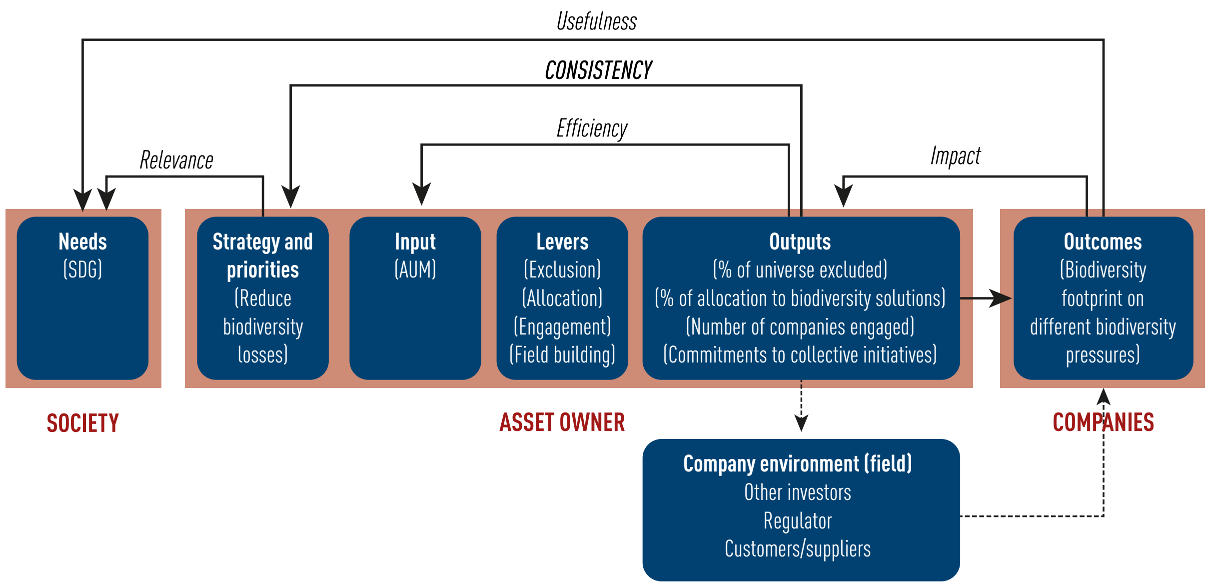
Finally, we would like to stress that subjective *preferences* should play a limited role where sustainable standards already exist, letting the choice of ambition and targets be rather driven by *priorities*. The idea that sustainability is mostly about preferences has developed with ESG customisation offerings. However, we argue that portfolio targets should always be derived from science-based or global standards, such as the Paris Agreement or the Net-Zero Asset Owner Alliance's Target-Setting Protocol. The resulting targets might vary according to methodologies, but not according to subjective preferences.

Incorporating financial risk considerations

For sustainable investors committed to fiduciary duty or facing financial risk constraints, monitoring the risk implications of pursuing sustainable goals is crucial. Sometimes, investors may discover a tradeoff between financial and extra-financial objectives, requiring an investment strategy that optimally balances both while considering individual constraints and responsibilities.

While a review and the management of the financial risks generated by sustainable investment strategies is outside the scope of this article, we propose a transparent top-down approach (see next section) to effectively combine financial and extra-financial objectives. The approach entails separating the pursuit of each objective to analyse tradeoffs effectively and implementing objectives through a strategic mix of selection and allocation decisions. For example, negative screening addresses the 'do no harm' sustainability objective and can be combined with a portfolio allocation

2. Theoretical model of change of a sustainable portfolio equity strategy (illustration with biodiversity)



Note: This diagram shows the relationship between societal needs, the various levers for building sustainable portfolios, and company actions. Based on this causal chain, we propose to position terms related to the notion of impact, such as *relevance*, *consistency*, *efficiency*, *impact* and *usefulness*, to highlight the connections between needs, strategy/priorities, invested capital, outputs and outcomes. Due to limitations in ESG data and methodologies, we suggest asset owners focus on what they can control: the consistency between their outputs and chosen strategy (a classification of coherent strategies is proposed below).

3. Classification of consistent sustainable strategies

		Portfolio initial allocation			Portfolio management		
Strategy	**Themes**	**Targeted companies**	**Negative screening**	**Weighting scheme**	**Shareholder engagement**	**Field building**	**'Output' metrics**
Sustainable	All	Companies whose behaviour and activities 'do no harm' to any SDGs	Covering all SDGs, based on revenues, physical metrics, controversies	Optimising risk and return under sustainability constraints: ● Negative screening		Publication of exclusion list	Alignment with 'do no harm' criteria, dynamic review of controversies
Transition	Specific	Companies whose behaviour and activities 'do harm' to certain SDGs, but where change is possible	Companies not prioritised for engagement + Companies where engagement has failed	Optimising risk and return under sustainability constraints: ● Negative screening ● Min/max share of 'targeted transition companies' (sustainability segment)	Systematically engaging on issues relating to the specific theme chosen	Publication of targets, engagement outputs and exclusion list	Engagement results
Solutions	Specific	Companies whose activities contribute positively to specific SDGs	Covering all SDGs, based on revenues, physical metrics, controversies	Optimising risk and return under sustainability constraints: ● Negative screening ● Min/max share of 'positive contribution companies' (sustainability segment)	Focusing on engagement related to activities (strategy, investments)		Share of 'positive contribution' investment
Ethical	All	Companies whose behaviour and activities are in line with ethical choices	Based on subjective preferences	Optimising risk and return under sustainability constraints: ● Negative screening			Respect of exclusion criteria

decision dedicated to managing risk. Similarly, within the allocation process, segmentation can be introduced to accommodate extra-financial objectives while dedicating stock-level allocation to the management of financial goals (see above).

A classification of coherent strategies
Considering the different types of sustainable investment and degrees of change possible, we can construct four main families of strategies and their associated levers (figure 3).

● ***Sustainable***: This strategy aims to align the portfolio's constituents with the original definition of sustainable development, focusing on companies that 'do no harm' to environmental and social issues. The exclusion lever, based on primary data, is favoured.

● ***Transition***: The goal here is to transform companies with negative impacts into sustainable ones. Engagement on specific themes and companies, combined with exclusion or tilting, is favoured. Both primary and secondary data are used to set exclusion thresholds and define science-based transition plans.

● ***Solutions***: This strategy aims to align a significant portion of the portfolio with solutions addressing environmental or social issues. Allocation ensures alignment with specific theme solutions, and dialogue with companies stimulates the reinforcement and development of these activities. Exclusions are used to ensure alignment with do-no-harm criteria.

● ***Ethical***: Unlike the three preceding strategies, this category allows for the integration of subjective preferences, such as religious or personal values, into investment criteria and targets.

Conclusion

Despite its growth, sustainable finance faces a credibility crisis and an internal crisis related to its role and levers. We began by reviewing the practices and benefits (and limitations) of the various choices faced by institutional asset owners in terms of the themes to address, the levers to employ and the data to use when constructing a sustainable portfolio. We show that the choices within these building blocks are interdependent.

We then proposed a classification of sustainable investments and a continuum of extra-financial ambition, from alignment to impact. We show that different pragmatic ambitions are possible, leading to four families of coherent sustainable investment strategies. The aim of this classification is to guide practitioners in building a sustainable strategy and promoting consistency between the ambition, themes, levers and data used.

Institutional asset owners with a fiduciary duty should consider financial risk management alongside the management of a strategy's extra-financial impact, in particular when those risks come as unintended consequences of an extra-financial objective. Our proposed classification offers the possibility of pursuing such a dual objective via a careful combination of selection and allocation decisions.

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Attribution analysis of greenhouse gas emissions associated with an equity portfolio

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Historical and cross-sectional attribution analysis of greenhouse gas emissions associated with financial portfolios has received little attention. Understanding the drivers that influence these emissions is essential to help portfolio managers set reduction targets and avoid 'portfolio greenwashing'.

This paper introduces an attribution method, inspired by environmental economics, that enables the disentanglement of five drivers influencing portfolio emissions.

To illustrate our model, we analyse a climate impact index and its benchmark over the period 2014-19. We show that the index reaches a similar decarbonisation rate to its benchmark by selecting the least emissions intensive companies within the sectors and companies that structurally reduce their emissions intensity.

In contrast, the benchmark achieves this decarbonisation mainly through sector allocation.

Investors are increasingly focused on managing greenhouse gas emissions in their portfolios to meet regulatory and stakeholder expectations. Despite existing climate metrics, investors face limitations in understanding and controlling the drivers influencing portfolio emissions. These challenges gave rise to initial attribution models inspired by financial performance attribution models (NZAOA [2023]). Environmental economics research has faced similar issues and developed decomposition methods to understand different drivers of global emissions, such as the 'Kaya identity' (figure 1) that expresses global emissions as the product of population, GDP per capita, energy intensity and carbon intensity (Kaya [1990]).

In a recent research paper (see Bouchet [2023] for more details), we propose a model for managing equity portfolio emissions inspired by decomposition methods from environmental economics. Our attribution model distinguishes five drivers applicable to metrics recommended by regulators and investor initiatives: sector allocation, intra-sectoral allocation, emissions intensity, sales and market capitalisation.

To illustrate our model, we analyse a climate impact index and its benchmark from 2014 to 2019. In cross-sectional analysis, the allocation within each sector driver explains nearly 70% of the difference in emissions intensity between the index and its benchmark, highlighting the index's ability to be less emissions-intensive while minimising sector effects. In historical analysis, both the index and its benchmark experience a 35% reduction in emissions over the period. Notably, the climate impact index achieves decarbonisation primarily through intra-sectoral allocation and selecting stocks that reduce emissions intensity, whereas the benchmark relies on sector allocation, with less representation of high-emission sectors.

This framework enables investors to manage the degree to which emissions and their trends are influenced either by sector biases (potentially increasing risk with limited climate mitigation impact) or by selecting companies within sectors with lower and decreasing emissions. This qualitative perspective helps mitigate the risk of 'portfolio greenwashing', as defined by Amenc et al (2022).

The rest of the article is organised as follows. The second section introduces climate change expectations investors face and the need to understand drivers influencing portfolio emissions. The next section adapts a decomposition from environmental economics to equity portfolio emissions attribution analysis. The final section presents an analysis of a climate impact index and its benchmark.

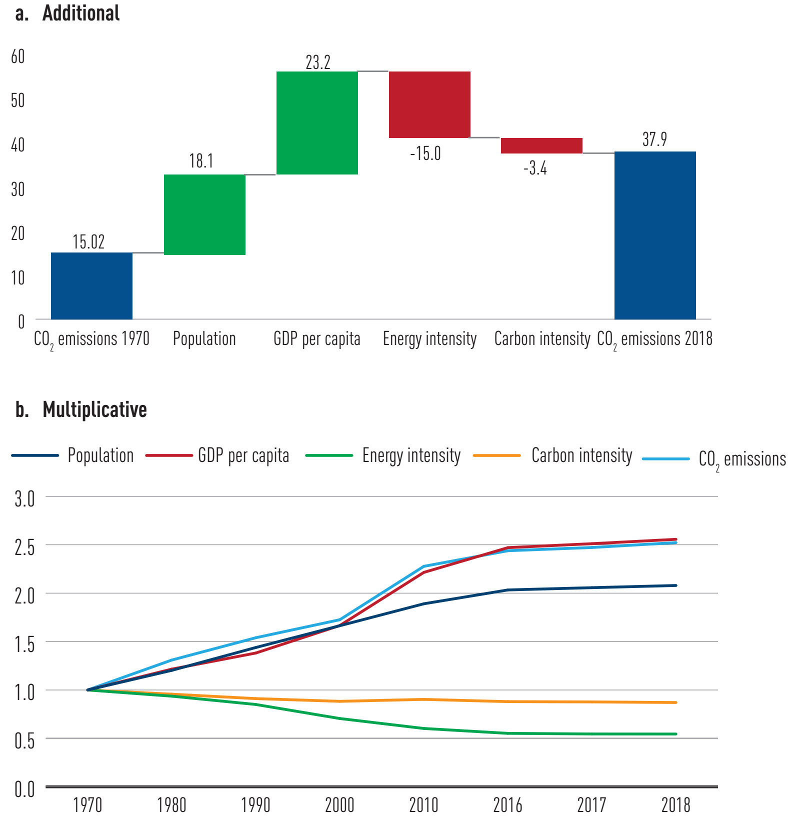
Emissions metrics in finance

Climate metrics serve investors in meeting regulatory reporting demands, monitoring progress towards objectives and managing climate-related portfolio risks. This section covers current emissions metrics associated with a portfolio and forward-looking metrics projecting potential future emissions. Investor expectations initially focused on reporting but have shifted towards reduction targets. Therefore, investors must understand the drivers influencing portfolio emissions to meet these new expectations.

Current performance metrics

Current portfolio-level performance metrics are generally constructed by aggregating company-level metrics. This article only addresses emissions-related metrics. While there are additional metrics for monitoring climate impact and risks, emissions benefit from a mature accounting system and share a common unit.

1. Historical analysis of global CO_2 emissions with the Kaya identity



Note: the evolution of emissions is decomposed into four driver effects: population, GDP per capita, energy intensity, and carbon intensity. In the additional decomposition (A) emissions are expressed in billion tons of CO_2, while they are normalised to 1 in the multiplicative decomposition (B). This decomposition highlights that despite an improvement in energy efficiency (energy intensity) and a reduction in carbon intensity, emissions primarily rise due to increased wealth per capita and population.

Data retrieved from Our World in Data: https://ourworldindata.org/grapher/kaya-identity-co2

At the company level, the Greenhouse Gas Protocol is the main framework for accounting and reporting. A central parameter is the emission scope under consideration, with Scope 1 accounting for direct emissions in production, Scope 2 for indirect emissions from purchased energy consumption, and Scope 3 for other indirect emissions along the value chain. The specific scope selection depends on the intended purpose of the metric. For emissions summation, using only Scope 1 is recommended to avoid double counting. For assessing a company's global warming impact, a wider scope may be relevant. The distribution of emissions across scopes varies by sector. For example, the utilities sector predominantly features Scope 1 emissions, while the consumer staples sector has a majority in Scope 3.

The portfolio-level aggregation of performance metrics assumes company comparisons are acceptable. At the company level, comparability is typically achieved by normalising absolute emissions based on activity size or the company itself. The three commonly used denominators for normalisation – 'sales', 'enterprise value including cash' and 'market capitalisation' – each have pros and cons (Ducoulombier and Liu [2021]). At the portfolio level, the resulting aggregate metric represents the average of these intensities or footprints, weighted by company share in the portfolio. Considering the assets under management also allows the absolute emissions to be calculated (PCAF [2022]).

Forward-looking metrics

To address the limited insights that existing metrics provide relative to specific climate scenarios, forward-looking metrics have been developed to assess a portfolio's alignment with the temperature change objectives of the Paris Agreement and other climate scenarios. ILB (2020) identifies four common steps to construct such metrics: 1) measuring portfolio-level climate performance, 2) selecting one or multiple scenarios, 3) converting macro emissions trajectories to portfolio trajectories, and 4) comparing the results of steps 1 and 3.

ILB (2020) highlights a wide disparity of results from different methodologies. For example, the implied temperature rise (ITR) of the Euronext Low-Carbon 100 index ranges from 1.5 to 3°C, depending on the methodology. These disparities limit the metrics' effectiveness in conveying a portfolio's alignment and monitoring portfolio emissions. Principles for Responsible Investment recommends that ITR metrics should be assessed alongside a range of additional climate metrics, including emissions (PRI [2021, 2022]).

From reporting to target-setting and monitoring emissions

Expectations for investors are moving from current and past portfolio performance towards future objectives. Since the Paris Agreement, various frameworks have emerged to guide and organise investor practices related to climate change reporting, target setting and monitoring. This subsection examines emissions metrics used by the following frameworks (figure 2):

Regulatory frameworks:
- Sustainable Finance Disclosure Regulation (SFDR)
- EU Climate Transition and Paris-Aligned Benchmarks Delegated Regulation (BMR)

Institutional investor coalitions:
- Target Setting Protocol of the Net-Zero Asset Owner Alliance (NZAOA)
- Net-Zero Investment Framework by the Paris Aligned Investment Initiative (PAII)

Mixed framework (developed as a voluntary initiative, but increasingly mandated by regulators):
- Task Force on Climate-Related Financial Disclosure (TCFD)

Analysis of these frameworks highlights three points. First, the emphasis on reporting has evolved, with the frameworks now placing greater importance on target setting. Second, several initiatives require *absolute* emissions targets. Third, including asset-level Scope 3 emissions is becoming increasingly mandatory in reporting and target setting.

The attribution model we propose is designed to assist investors in meeting evolving expectations for emissions management (NZAOA [2023]). By

2. Emissions metrics across five frameworks

	SFDR	BMR	TCFD	NZAOA	PAII
Scope 1 absolute emissions	R		R+T	R+T	R+T
Scope 1+2 absolute emissions	R		R+T	R+T	R+T
Scope 1+2+3 absolute emissions	R		(R)	R+T*	
Scope 1 footprint (/€m invested)	R	R+T	(R)		R+T
Scope 1+2 footprint (/€m invested)	R	R+T	(R)		R+T
Scope 1+2+3 footprint (/€m invested)	R	R+T*	(R)		
Scope 1 intensity (/€m sales)	R		R	R+T	
Scope 1+2 intensity (/€m sales)	R		R	R+T	
Scope 1+2+3 intensity (€m sales)	R		(R)	R+T*	

Note: footprint represents the emissions divided by the enterprise value or by the market capitalisation. R: Reporting; T: Target setting; () optional; * initially only on most material sectors

analysing drivers that account for changes in a portfolio's relative or absolute emissions, including asset-level Scope 3, the model serves several purposes. It facilitates an understanding of each driver's role in reducing a portfolio's emissions – beyond relying on sector allocation – which is particularly useful for assessing a portfolio's potential to achieve reduction targets. It also provides inputs for shareholder engagement and transparency for public reporting (NZAOA [2023]).

An attribution method for portfolio emissions

In this section, we propose an attribution model to analyse different emissions performance metrics of an equity portfolio, from a cross-sectional and historical perspective, based on decomposition principles developed in environmental economics.

Theoretical principles of the index decomposition analysis

Various works in environmental economics identify the drivers of observed changes on environmental variables. This sub-section introduces index decomposition analysis (IDA) as it is the most easily applicable method for a financial portfolio.[1]

Consider G as an aggregate value of sub-categories h (eg, the sum of emissions associated with different instruments), and n drivers contributing to these sub-categories' emissions $x_1, x_2, \ldots, x_n$ (eg, weight in portfolio, carbon intensity, sales, etc).

$$G = \sum_h x_{1,h}.x_{2,h} \ldots x_{n,h}$$

The goal of IDA is to understand historical aggregate change from G^0 to G^T as an (1) *additive* or (2) *multiplicative* operation between drivers.

$$G^T - G^0 = \Delta G_{X_1} + \Delta G_{X_2} + \cdots \Delta G_{X_n} \quad (1)$$

$$\frac{G^t}{G^0} = I_{x_1}.I_{x_2} \ldots I_{x_n} \quad (2)$$

The reasoning behind the IDA is to derive the aggregate value formula over time and isolate the contribution of the n drivers. As developed in Ang (2015), the additional effects of the k^{th} driver is given by

$$\Delta G_{x_k} = \sum_h L\left(g_h^T, g_h^0\right).\ln\left(\frac{x_{k,h}^T}{x_{k,h}^0}\right) \quad (1)$$

$$I_{x_k} = \exp\left(\sum_h \frac{L\left(g_h^T, g_h^0\right)}{L\left(g^T, g^0\right)}.\ln\left(\frac{x_{k,h}^T}{x_{k,h}^0}\right)\right) \quad (2)$$

where

$$L(a,b) = \frac{a-b}{\ln a - \ln b}$$

and g_h is in our case the emissions of the instrument h.

The choice between additive and multiplicative methods depends on the analysis' focus, with additive decomposition preferred for multi-year aggregate analysis and multiplicative decomposition preferred for identifying changes in trends.

Identity for portfolio emissions

We present the identity for absolute emissions below.

$$G_p = \sum_H \sum_S w_{sp}.w_{hs}.\left(CIs1_h + CIs2_h + CIs3_h\right).$$

$$Sales_h.\frac{1}{Mktcap_h}.MktValue_p$$

The drivers can be grouped into three categories:

- ***Investment portfolio reallocation***. The manager has a direct impact on sector and intra-sectoral allocation. The control of the sector allocation driver is particularly important and can be seen as an artifice relative to climate impact, allowing reduction of emissions by reducing exposure to emissive sectors. Sectoral deviations from a benchmark can cause large tracking errors, increasing financial risk.
- ***Emissions intensity*** (real world emissions reduction). Companies can lower their emissions intensity in three scopes (1, 2 and 3). Choosing companies that improve intensity is influenced by portfolio reallocation decisions. Throughout the article, Scope 1 + 2 emissions rely on reported data, while Scope 3 emissions are consistently estimated. This choice is driven by the lack of comparability in Scope 3 reported emissions and the goal of providing historical analysis.
- ***Economic drivers***. These drivers link relative emissions and absolute emissions. Increasingly, frameworks recommend absolute emissions target-setting and monitoring. It is therefore essential to analyse absolute emissions and understand the economic drivers that influence them.

  Sales – a company's absolute emissions might be explained from a change in its emissions intensity or its sales.

  $\frac{1}{Mktcap_h}$ – the share of emissions attributed to an investor depends on the market value of a company (for a fixed amount invested in this company).

  $MktValue_p$ – as the market value of a portfolio increases, the investor's responsibility in terms of emissions increases.

Cross-sectional and historical analysis

Equity portfolio analysis can be historical or cross-sectional, such as against a benchmark. Depending on this choice and the type of metric analysed, only some drivers will influence the attribution model (figure 3).

Results

We illustrate the attribution model by comparing two portfolios: a conventional index of the US equity universe (500 stocks – the '*benchmark*') and a climate impact index[2] built on the same universe (the '*index*').

Cross-sectional analysis

A portfolio's cross-sectional analysis will only be influenced by sector allocation and intra-sectoral allocation. Figure 4a

1 The structural decomposition analysis, the other main method, relies on the same mathematical principles but adds the input-output analytical framework developed by Wassily Leontief to the approach.

2 Scientific Beta's United States Climate Impact Consistent EU PAB Compliant index.

3. Drivers influencing the attribution model by type of analysis and metrics

Analysis		Cross-sectional			Historical		
Metrics		**Absolute**	**Intensity**	**Footprint**	**Absolute**	**Intensity**	**Footprint**
Allocation	Sector allocation	✓	✓	✓	✓	✓	✓
	Intra-sectoral allocation	✓	✓	✓	✓	✓	✓
Emissions intensity	Intensity Scope 1				✓	✓	✓
	Intensity Scope 2				✓	✓	✓
	Intensity Scope 3				✓	✓	✓
Economic variables	Sales				✓		
	1/Market cap				✓		
	Value	✓			✓		

shows the drivers explaining the difference between the absolute emissions of the benchmark (left) and the climate impact index (right). The climate impact index's lower decarbonisation can be explained by its lower exposure to high emitting sectors. However, the intra-sectoral allocation shows that, even with similar exposure to these sectors, the index would have lower emissions because it is less exposed to the most emissions intensive companies. Sector and intra-sectoral allocation have a relatively similar effect when considering absolute emissions.

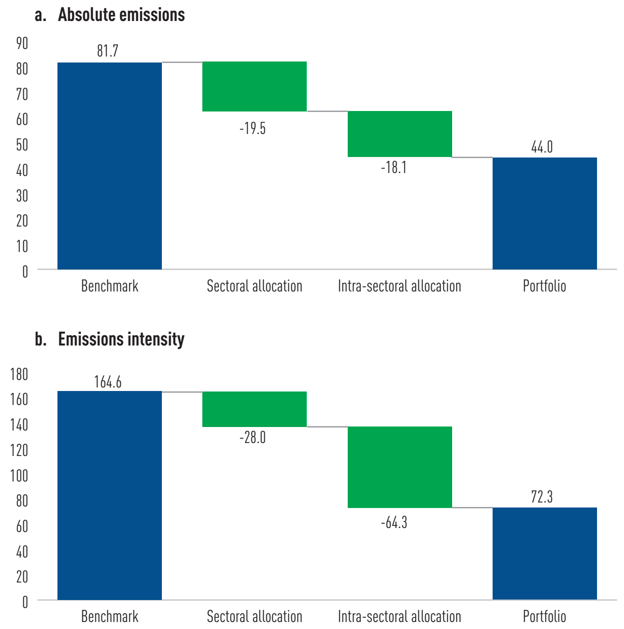
However, the weight of the two drivers in explaining the cross-sectional decarbonisation of the index depends on the metric considered. When analysing emissions intensity instead of absolute emissions, the results are different: the intra-sectoral allocation driver explains nearly 70% of the decarbonisation (figure 4b). The choice of metric for setting and monitoring targets is crucial, affecting the explanation of decarbonisation.

We want to identify sectors influencing these drivers, determining which sectors are over/underweighted by the climate impact index compared to the benchmark. The rearranged attribution model, presented in figure 5, examines these effects.

This analysis shows that the cross-sectional difference is mainly explained by the energy and utilities sectors, although the drivers differ for each sector. Within the energy sector, the main effect is the sector allocation (left bar), while for the utilities sector, it is the intra-sectoral allocation (left bar). These results allow confirmation that the index provider has taken into account the exclusion criteria of the EU Benchmarks regulation and that they selected the 'best in class' within the other emissions-intensive sectors, in particular the utilities sector.

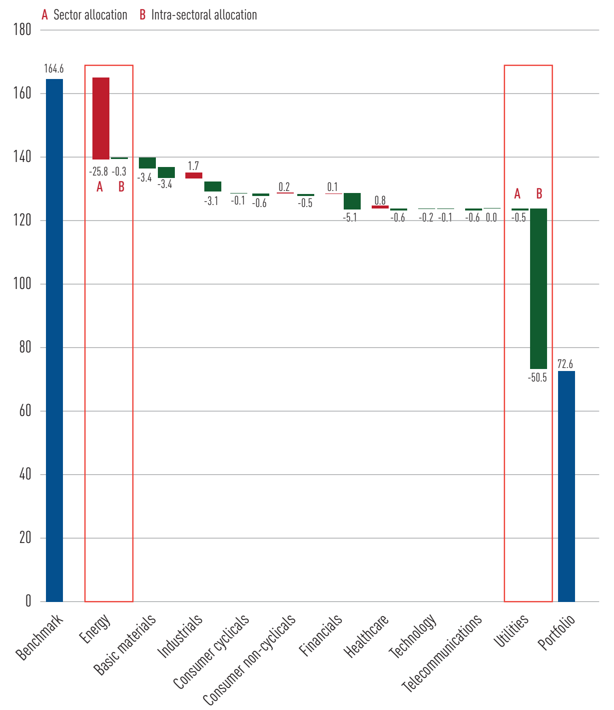
Historical analysis
The preceding analysis explains the difference between the climate impact index's emissions performance and its benchmark's performance at a given time. However, targets for decarbonisation

4. Cross-sectional analysis on emissions



Note: the absolute emissions correspond to the emissions on Scope 1 + 2 associated with an investment of $1m in each instrument for the fiscal year 2019. The emissions intensity corresponds, for each instrument, to the average greenhouse gas emissions on Scope 1 + 2 divided by $1m of sales of the underlying companies.

5. Cross-sectional analysis on emissions intensity by sector



Note: the emissions intensity corresponds, for each instrument, to the average greenhouse gas emissions on Scope 1 + 2 divided by $1m of sales of the underlying companies. For each sector, the left bar corresponds to the sector allocation driver and the right bar to the intra-sectoral allocation driver.

objectives must be set over time. It is therefore essential to complement the cross-sectional analysis by a historical analysis.

This analysis introduces new drivers, including company emissions intensity (Scope 1, 2, and 3), sales and market capitalisation, reflecting the decarbonisation 'trend' of companies over time.

When examining absolute emissions, economic drivers (sales and market capitalisation) must be considered. A simplified example involving a portfolio with two equally weighted stocks illustrates how changes in emissions intensity, sales, and market capitalisation influence portfolio performance metrics – refer to figure 6, columns (1), (2) and (3) (a), (b) (c).

- If the market capitalisation of company A doubles, the average emissions intensity will increase because of the larger weight in company A, which is more intensive. Meanwhile, the footprint of the portfolio will decrease because absolute emissions are constant while the portfolio AUM is larger.
- With a hypothesis of an equally weighted portfolio, the AUM should be redistributed in the two companies. Such a change has no impact on the average intensity but has an impact on footprint and absolute emissions. Although the AUM is now 50% *higher* than in the initial state, the absolute emissions of the portfolio have *decreased*.
- The effect is amplified if we simulate an outflow of AUM.

This example illustrates the importance of considering several metrics to analyse a portfolio and the effects of economic drivers. The market capitalisation driver is difficult for a portfolio manager to control but has important short-term effects, so neutralising it when comparing the emissions performance of different instruments is relevant.

Figure 7a shows that most of the benchmark's historical decarbonisation during the 2014-19 period comes from sector allocation. The emissions intensity driver contributes positively to the absolute emissions (on Scope 1 + 2 + 3). The main driver contributing to the climate impact index's historical reduction is the intra-sectoral allocation (figure 7b). The emissions intensity driver also contributed to reducing emissions, while the sales driver increased them. This analysis shows how two similar decarbonisation rates can be achieved through different drivers.

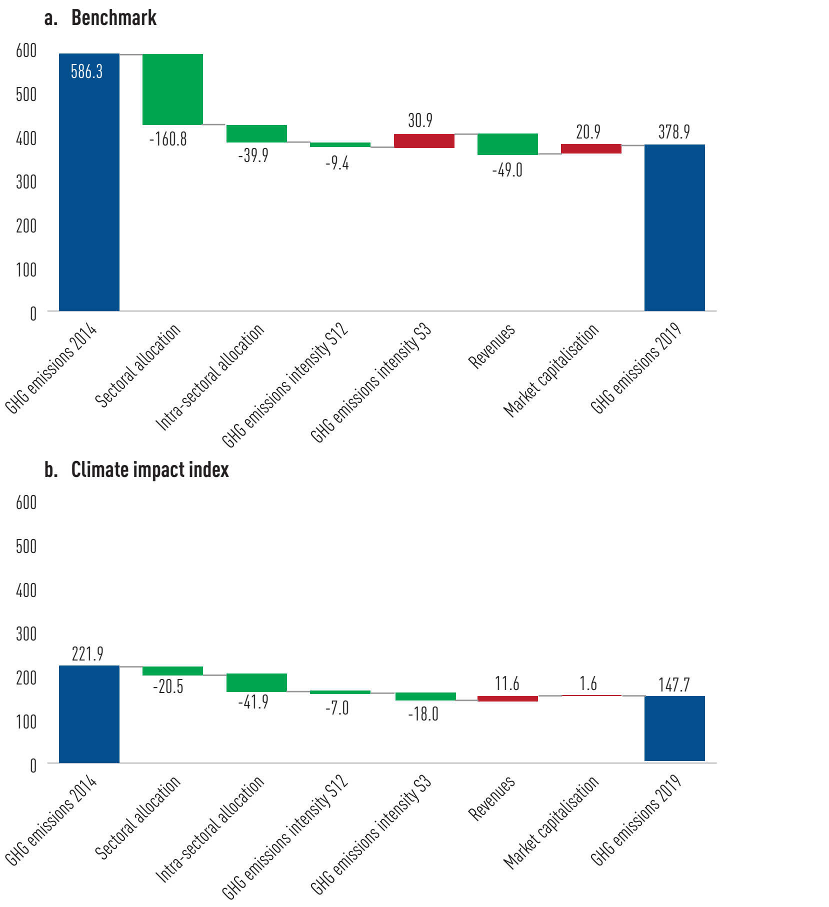
Using a multiplicative decomposition method provides insight into the historical trends of each driver. For the benchmark, sector and intra-sectoral allocation

6. Illustration of drivers' influence on a simplified portfolio of two stocks

Companies	Reference		(1) Emissions intensity increase		(2) Sales increase		(3) Market capitalisation increase					
							(a)		(b)		(c)	
	A	B	A	B	A	B	A	B	A	B	A	B
(1) Portfolio weight	50%	50%	50%	50%	50%	50%	**67%**	**33%**	50%	50%	50%	50%
(2) AUM ($m)	5.0	5.0	5.0	5.0	5.0	5.0	**10.0**	5.0	**7.5**	**7.5**	5.0	5.0
(3) Market capitalisation ($m)	20	20	20	20	20	20	**40**	20	**40**	20	40	20
(4) Share of market capitalisation (2)/(3)	25%	25%	25%	25%	25%	25%	25%	25%	**19%**	**38%**	13%	25%
(5) Emissions intensity (tCO$_2$e/$m)	100	10	**200**	10	100	10	100	10	100	10	100	10
(6) Sales ($m)	10	10	10	10	**20**	10	10	10	10	10	10	10
(7) Emissions (tCO$_2$e) (5)*(6)	1,000	100	**2,000**	100	**2,000**	100	1,000	100	1,000	100	1,000	100
(8) Emissions of portfolio (tCO$_2$e) (4)*(7)	250.0	25.0	**500.0**	25.0	**500.0**	25.0	250.0	25.0	**187.5**	**37.5**	125.0	25.0
Portfolio												
AUM ($m)	10		10		10		**15**		**15**		10	
Average emissions intensity (tCO$_2$e/$m) (1A)*(5A)+(1B)*(5B)	55		**105**		55		**70**		55		55	
Average emissions footprint (tCO$_2$e/$m) (1A)*(7A)/(3A)+(1B)*(7B)/(3B)	27.5		**52.5**		**52.5**		**18.3**		**15.0**		**15.0**	
Absolute emissions (tCO$_2$e/$m) (8A)+(8B)	275		**525**		**525**		275		**225**		**150**	

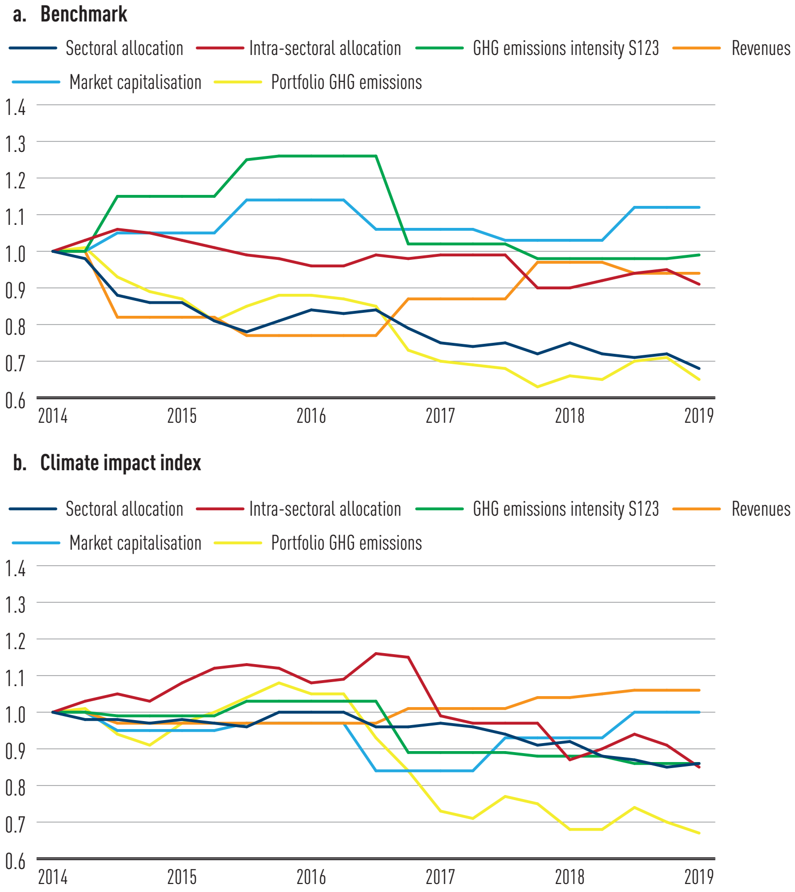
Note: the first column (Reference) represents the portfolio at the beginning of the period, while the four following columns represent the portfolio at the end of the period with different hypothesis. Figures in red underlined represent the initial change in one driver, and figures in red represent the indirect effects of this change.

7. Historical analysis on absolute emissions



Note: The absolute emissions correspond to the greenhouse gas emissions in tCO$_2$e (tons of CO$_2$ equivalent) per $1m dollars invested in each instrument. They are calculated considering a Scope 1 + 2 + 3.

8. Multiplicative analysis on absolute emissions



Note: each driver is normalised to 1.

intensity, sales, and market capitalisation show more volatility (figure 8a). Additionally, although the index, on average, decarbonised similarly to its benchmark, it experienced an emissions increase from 2014 to 2016 (figure 8b). This multiplicative decomposition aids portfolio management by monitoring the evolution of drivers over shorter time periods.

Conclusion

In response to growing expectations of regulators and stakeholders for investors to manage the greenhouse gas emissions associated with their portfolios, we introduce an attribution analysis framework inspired by environment economics, allowing for both cross-sectional and historical analysis.

The proposed model parses the impact of three types of drivers: i) portfolio manager's choices, ii) company emissions intensity and iii) economic drivers affecting total emissions. We illustrate this model by examining a climate-focused index and its benchmark. Despite both achieving similar decarbonisation rates, the climate impact index primarily reduces emissions through intra-sectoral allocation and lowering companies' emissions intensity, while the benchmark achieves this mainly through sector allocation. Understanding each driver's role helps verify if a portfolio effectively reduces emissions, preventing reliance solely on sector allocation and avoiding the risk of 'portfolio greenwashing'.

This attribution analysis complements existing forward-looking approaches. While metrics like implied temperature rise are useful for communication, they have limitations in managing portfolio emissions (PRI [2021]). It's crucial to distinguish methods for setting long-term alignment targets from those assessing and monitoring these targets. The attribution analysis framework in this article aligns with this assessment goal, emphasising the need for predefined portfolio-level targets compatible with global emission pathways.

From a practitioner perspective, it is possible to create a single metric to gauge a portfolio manager's decarbonisation effectiveness. This metric can emphasise the manager's skill in selecting top-performing stocks within sectors and ability to choose companies with decreasing emissions intensity. The metric can also eliminate the sector effect, preventing it from being perceived as 'portfolio greenwashing', as well as neutralising effects beyond the portfolio manager's control.

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Simulation of equity portfolios returns in macroeconomic regimes

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We provide a list of macro-economic variables and a definition of regimes that significantly impact the probability distribution of equity returns, while having stable properties in- and out-of-sample.

These stable regimes specifically capture large macroeconomic moves and can hence support a highly informative scenario analysis based on long-term conditional simulations.

The behaviour of equity portfolios can be efficiently extrapolated in different regimes over multiple economic cycles, thus making conditional simulations an important ingredient of an investment process.

Introduction

The objective of simulating the returns of equity portfolios is to challenge the features of a strategy as observed from its historical track. Simulated returns offer an alternative view on the performance of a strategy by providing a set of *plausible alternatives* to its historical returns. Importantly, they introduce the notion that the characteristics of a strategy's returns should be represented by a range instead of a fixed number, as should any process governed by randomness.

By exploiting information about the statistical distribution of returns, notably in different market conditions, that the historical track provides, simulations help to access out-of-sample information that do not limit the outcome of a strategy to its observed returns. Simulations thus provide a key input into investment decisions.

The simulation of returns requires two key ingredients. First, a statistical distribution that reproduces the statistical properties of portfolios returns. Second, a sample of returns that will be used to calibrate the chosen distribution.

The choice of a statistical distribution fitting a particular returns sequence has been studied extensively. The so-called stylised facts of equity returns have been described in multiple places (Mandelbrot [1997]; Fama [1965]; Campbell et al [1998]), and good distributions are readily available to simulate them. We refer the reader to Bouchaud and Potters (2003) and Jondeau, Poon and Rockinger (2007).

Choosing a sample to calibrate these distributions is far more problematic. In the long term, the statistical properties of financial instruments, such as their expected returns, are not stationary. Volatility too is not stable over time, and tends to cluster (Engle [2002]; Bollerslev [1987]) around its long-term average. This variability is evidently problematic in the context of decision making. The use of regimes, with distinct, stable and robust returns' distributions, is therefore more practical. These regimes must also be economically meaningful, and their properties significantly different from that of the long-term returns.

Although the use of macroeconomic regimes is common among practitioners, there is no consensus on their actual definition. The academic literature is also mixed on the matter. It is widely documented that changes in macro variables influence equity return (Flannery and Protopapadakis [2002]) but the identification of the relevant macroeconomic variables and the extent their impact on equity returns is often challenged as varying period, frequency and time horizon often lead to different results (Cutler et al [1989]; Goyal et al [2021]).

In the context of equity portfolios, the works of (Amenc et al [2019]; Esakia and Goltz [2023]) identify a set of macro-economic variables and market regimes relevant from the angle of equity portfolio returns. In a recent research paper (see Vaucher et al [2024]), we examine the statistical properties of these regimes to shed light on their relevance for investments decisions.

Macro-economic regimes and investment decisions

For regimes to provide useful and robust input into the decision-making process, they must satisfy the following conditions.

- ***Differentiation with full sample***: The distribution of returns within regimes must be sufficiently different from long-term returns so that their occurrence impacts the portfolio's returns and have thus reason to be considered an input in an investment process.
- ***In-sample stability***: Regimes must be sufficiently stable so that any return sub-sample within each regime must share characteristics with the rest of the regime's returns. Stability of parameters is also important to generate reliable simulations.
- ***Out-of-sample robustness***: Investment decisions are forward-looking, hence it is important that within-regime return distributions remain stable in future periods. This crucial condition is often overlooked in the literature.

Definition of regimes

In this paper, we have selected macro-economic variables using the prescriptions of Amenc et al (2019), which define a protocol for assessing their relevance in the context of equity investments, ensuring that the macroeconomic variables have a documented impact on equity returns, with a solid theoretical justification. We refer the reader to the paper for more details.

The selected macroeconomic variables and their regimes are shown in figure 1. The fundamental equity risk factors (ERFs) are obtained from Scientific Beta and are designed such that their returns are orthogonal to market returns. This means that there is no correlation between these ERFs and the market factor.[1]

To define regimes, we use monthly times series going back to 1974. Changes in the underlying variables are defined as a change (absolute or percentage wise) with respect to the previous month, whereas levels correspond to the value of the variable at the end of each month.[2,3]

Both definitions produce regimes associated with significant difference in performance for equity factors. Regimes are defined as the days belonging to months in the top quartile ('high regime') or bottom quartile ('low regime'). For instance, the high-volatility regime represents the months when market volatility is in its highest quartile at the end of the month. According to this definition, regimes are not only defined by the very days during which the value of the macro-indicator is at its highest (or lowest), but also the few weeks around that moment belonging to the same month. This is more in line with investment practice whereby investment views are typically implemented on a monthly or quarterly basis. Each regime contains about 3,000 daily returns, though the months belonging to the same regime are not necessarily contiguous.

1. Macroeconomic variables used to define regimes

Macroeconomic variable	Definition	Start date	Change	Level
Short-term rates	Three-month US treasury bills (DTB3)	1954	Absolute	Yes
Market index	Broad US market index	1970	Percentage	No
Inflation	CPI (CPIAUCSL until 2003), then 10-year breakeven inflation rate (T10YIE)	1947	Absolute	Yes
Long-term rates	Treasury instruments 10-year constant maturity yield (DGS10)	1962	Absolute	Yes
Dollar index	Strength of dollar against a basket of major currencies (DXY)	1973	Percentage	Yes
Oil	Spot crude oil price (WTISPLC and DCOILWTICO)	1946	Percentage	No
Credit spread	Difference between Moody's BAA (DBAA) and AAA (DAAA) corporate yields		Absolute	Yes
Time spread	Difference between Long-term and Short-term rates		Absolute	Yes
Market volatility	Instant GARCH volatility of Market Index until 1990, then VIX (VIXCLS)	1970	Percentage	Yes
ERF Volatility	SB ERF Low-Risk	1970	Percentage	No
ERF Size	SB ERF Size	1970	Percentage	No
ERF Profitability	SB ERF Profitability	1970	Percentage	No
ERF Value	SB ERF Value Equity	1970	Percentage	No
ERF Investment	SB ERF Investment	1970	Percentage	No
ERF Momentum	SB ERF Momentum	1970	Percentage	No

Notes: Scientific Beta Equity Risk Factors are abbreviated as SB ERF. Tickers from the Federal Reserve Bank (FRED) are in parenthesis.

2. Differences in returns and risk (annualised volatility) between regimes returns and long-term returns

	ΔE[R] (%)				ΔVolatility (%)			
	Change down	Change up	Level low	Level high	Change down	Change up	Level low	Level high
Credit spread	9.81*	-4.88	-0.59	7.41	-1.45**	2.82***	-3.89***	2.48***
Dollar index	15.64**	-10.48*	-	-	0.32	0.82**	-	-
Inflation	-4.51	6.38	-0.43	-4.58	2.96***	-0.39	4.14***	-2.31**
Long-term rates	-1.24	-8.31	-	-	3.34***	-1.31	-	-
Market index	-51.33***	85.62***	-	-	2.43***	-1.40	-	-
Oil	-7.94	8.58	-	-	2.41***	-1.18**	-	-
Short-term rates	-4.76	-8.84*	1.17	0.49	4.51***	-1.74*	3.82***	-2.37**
Time spread	-2.69	-3.08	-2.69	-5.37	1.12***	3.62***	1.21***	1.86
Market volatility	40.97***	-36.28***	25.88***	-26.71***	-0.55	2.32***	-8.47***	6.76***
ERF Volatility	-1.51	-9.48	-	-	-1.72*	2.72***	-	-
ERF Size	-16.31***	18.93***	-	-	0.88***	-0.50	-	-
ERF Profitability	1.26	-1.83	-	-	0.51	2.26***	-	-
ERF Value	-2.90	-0.66	-	-	-1.03	1.20	-	-
ERF Investment	2.54	-4.20	-	-	-0.05	0.99***	-	-
ERF Momentum	0.52	-12.33**	-	-	1.50***	1.68***	-	-

Notes: The p-values corresponding to a 1%, 5% and 10% threshold are denoted by (***), (**) and (*). The p-values for the volatility were obtained using the Levene test.

Empirical results

To assess the in- and out-of-sample stability and robustness of regimes, we have used the returns of the Scientific Beta United States Cap-Weighted index (which is comprised of the 500 largest US stocks) between June 1974 and January 2023, a period over which we have data available for both macroeconomic and equity risk factors.

We first evaluated whether the within-regime distributional properties of returns, namely expected returns and volatility were statistically different from long-term ones. The results are shown in figure 2. The standard errors were obtained via the Welch and Levene test for returns and volatility, respectively.

Although the expected returns and volatilities within regimes are significantly different from their long-term returns, the difference in volatility is more systematically present. Hence, regimes impact more risk than returns. For instance, an increase of credit spreads, which indicates a higher risk of default, or a decrease in short term rates, tend to coincide with a significantly higher volatility in the market without a clear impact on direction. As expected, regimes related to the market itself and its volatility have the strongest impact on returns.

We then examined the stability of the returns' distribution inside regimes by using the sample excess kurtosis. The kurtosis is a powerful indicator of stability, since it is directly proportional to the variation of the volatility within a sample, and indirectly to the variation of expected returns. Less excess kurtosis is therefore associated with more stable risk and performance within a sample. Figure

1 Their definition can be found in Amenc and Goltz (2016).
2 See, eg, Esakia and Goltz (2023) or Amenc et al (2019).
3 It is not possible to define level-based regimes for all macroeconomic variables, since some economic indicators accrue over time, eg, market indices. Regimes based on indicators that are notably affected by inflation, such as oil prices, also cannot be level-based. Similarly, changes in rates are better defined in terms of absolute point rather than percentages.

3 shows that the excess kurtosis present in almost all regimes is much lower than that measured in long-term market returns. As the market excess kurtosis is around 17, the reductions observed are economically important in many cases, thereby confirming that the properties of returns within each regime are often significantly more stable than generic long-term returns.

Another measure of stability is obtained via the Kolmogorov-Smirnov (KS) test. The KS test is a non-parametric test that returns the probability for two returns samples being drawn from the same distribution. A low value signifies that the probability distributions are different. We have drawn random samples corresponding to a quarter of the returns within each regime and measured their distance to the remaining returns in the same regime using the KS test. We found that in general, the distribution of any sample within the regime is much closer to that of its regime than long-term returns. This confirms not only that equity returns within regime have a distinct statistical signature, but also that these properties differ from those of long-term returns.

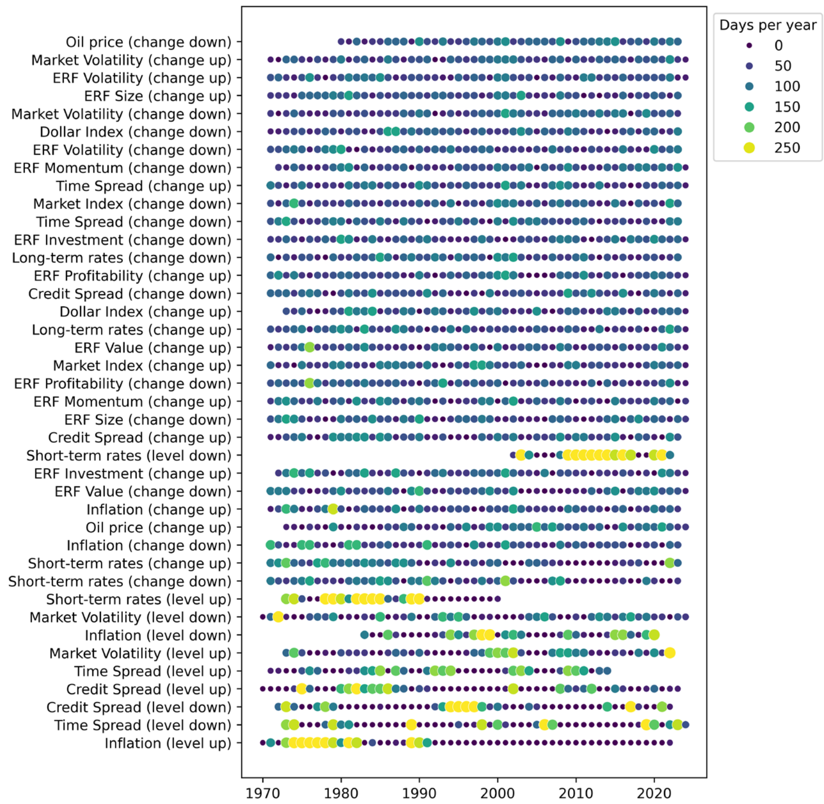
As reliability of regimes characteristics out-of-sample is key for investment decisions, in unreported results we test whether these findings are robust OOS, too, and obtain similar results for the KS test.[4]

3. Differences between the excess kurtosis of the regimes returns and long-term market returns

	Difference in kurtosis between regime and long-term returns				In-sample KS test			
	Change down	Change up	Level low	Level high	Change down	Change up	Level low	Level high
Credit spread	-10.76	-12.49	-11.01	-7.62	0.49 (0.42)	0.45 (0.03)	0.50 (0.04)	**0.47 (0.03)**
Dollar index	17.16	-3.88	-	-	0.51 (0.20)	0.54 (0.24)	-	-
Inflation	-6.15	-12.62	-5.49	-14.49	0.46 (0.14)	0.55 (0.49)	0.50 (0.10)	**0.54 (0.28)**
Long-term rates	7.23	-14.08	-	-	0.50 (0.31)	0.54 (0.32)	-	-
Market index	-12.38	-12.95	-	-	0.52 (0.00)	0.49 (0.00)	-	-
Oil	-11.08	-12.36	-	-	0.51 (0.06)	0.47 (0.34)	-	-
Short-term rates	6.13	-13.91	-3.76	-14.54	0.51 (0.23)	0.50 (0.25)	0.49 (0.27)	**0.50 (0.30)**
Time spread	-9.76	8.75	-5.10	14.33	0.55 (0.39)	0.53 (0.25)	0.52 (0.27)	**0.50 (0.49)**
Volatility	-12.07	-9.21	-15.83	-15.08	0.50 (0.04)	0.57 (0.00)	0.55 (0.00)	**0.54 (0.00)**

Notes: Another estimation of in-sample stability is obtained by performing the KS test between random samples drawn within the regime. The number in parenthesis corresponds to the same test performed between the samples drawn within the regime and long-term market returns. Market returns used for this test span a period between 1970 and 2024.

4. Historical representativeness of regimes



Other considerations pertaining to the use of regimes

Two important issues also affect the use of regimes in an investment process, namely the typical length of regimes (or duration), as well as their historical representativeness. For instance, a regime corresponding to the volatility going up might last a few weeks, or a couple of months at most. Most regimes have a duration of about a quarter, with a few exceptions, such as inflation – and rates-related regimes that last more than a couple of years on average. The historical representativeness of regimes also impacts their use for portfolio analysis. By historical representativeness, we mean that the phenomenon is not isolated but recurring in time. We attempt to illustrate it in figure 4.

Most regimes are well spread over time and level-based regimes tend to cluster around certain periods, hence the analysis of portfolios during these may be biased.[5] Regimes corresponding to levels of inflation and rates are historically very biased, and therefore should be used very carefully in investment decisions.

Linear extrapolations and out-of-sample simulations

In the context of investment decisions, an understanding of the impact of regimes on the invested portfolio is a key piece of information, as it determines the action to be taken in response to the macroeconomic forecast. However, a robust impact analysis is often hard to obtain because of the typical shortness of portfolios track record. To obtain statistically significant information on the portfolio's behaviour in different regimes, data covering several business cycles would be desirable, but it is rarely available.

One way to improve the statistical

4 See Vaucher et al (2024) for further details.

5 This fact suggests that macro-based regimes help explaining the well-documented return volatility clusters observed in practice.

significance of the performance and risk estimates in different regimes is to extrapolate the returns of the portfolio outside of its historical sample. This is possible by using its exposures to different risk factors, which are available over longer periods of time.

We define extrapolated returns $\hat{r}$ as follows:

$$\hat{r}_t = \sum_{l=1}^{L} \beta_l f_{lt}$$

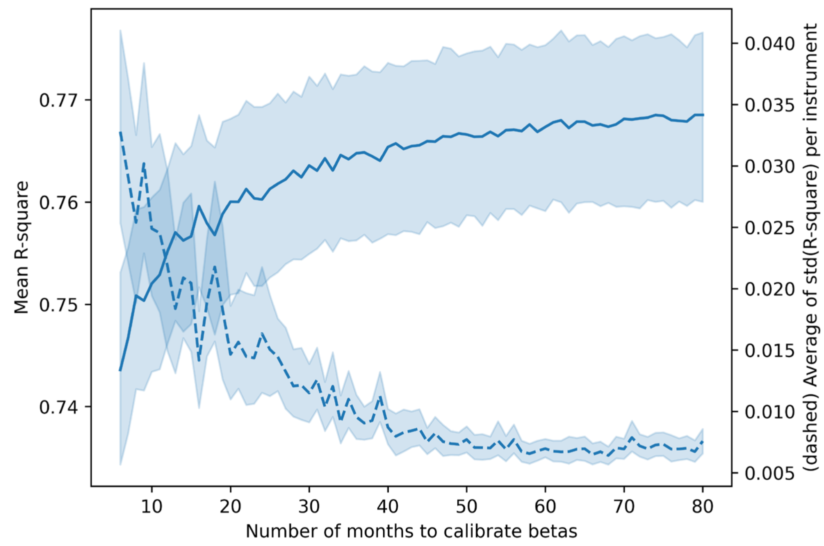
where β_t corresponds to the exposures of the portfolio to the risk factors f_t measured using its historical track record, for each of the l = 1, 2, ...,L factors considered.

Extending a portfolio's return with this method is advisable under two conditions. First, the precision of the model, as measured by its R-squared for instance, must be high, ie, it must provide a reliable description of the portfolio's returns.

Second, the strategy followed by the portfolio must be sufficiently stable, and expressible in terms of exposure to risk factors. For instance, the extension of a strategy based on investing in undervalued stocks, or 'Value' strategy, is likely well extrapolated outside of its historical sample. Similarly, a purely sector-based strategy is readily extendable using sector-based risk factors. In this context, statistically insignificant exposures to risk factors are to be treated with care, since they likely correspond to an uncontrolled, or opportunistic, component of the portfolio's strategy. Therefore, they are best set to zero, since their dynamical nature cannot be simulated out of sample with a simple factor model. Similarly, we have also set the residual returns $r - \hat{r}$ to zero (here r corresponds to the portfolio's historical returns) as we assume that they are by nature not reproducible, and therefore their simulation using historical statistics is unreliable.

To test the reliability of a portfolio's long-term extrapolation, we have considered several strategies involving funds with very long track records (>40 years). We have split their historical track into a calibration and test set. The size of the calibration set ranges from six months to 10 years of daily returns. The dates belonging to the calibration set are not necessarily adjacent and they are taken at random. This set is then used to measure a portfolio's exposures to risk factors. The portfolio's returns are then extrapolated on to the test set, which consists of the entire historical track, less the calibration set. In figure 5, we plot the R-squared of extrapolated returns compared to true returns.

5. R-squared of the extrapolated returns and standard deviation of the R-squared over all funds



Notes: R-squared of the extrapolated returns (solid line) and standard deviation of the R-squared over all funds (dashed line). The extrapolation was formed using exposures measured over random calibration sets of different sizes. The R-squared was evaluated outside of the exposures' calibration set.

The mean R-squared of the extrapolated returns is high, on average around 75%. This is remarkably close to the full-sample R-squared of 77%. Increasing the length of the calibration set used to estimate exposures does improve the precision of the extrapolations, but past about five years, only with a marginal increase. The overall quality of the extrapolation, as measured by the standard deviation of the R-squared, also reaches its maximum with calibration sets of about five years. Said differently, these simulations show that extending the funds' systematic returns using betas estimated even over a limited history delivers a precision comparable to doing the same with betas estimated over the full history, hence extrapolating returns through factor exposures is a reliable tool for performance analysis

Apart from enabling a robust analysis of regimes impacts on the portfolio's behaviour, the linear model approach has another important advantage, namely that it facilitates the simulation of reliable out-of-sample returns. Because risk factors have very long-term historical tracks, their properties within each regime are estimated with high statistical significance. It is therefore possible to efficiently calibrate probability distributions to simulate their returns, including their correlations and moments. The within-regime out-of-sample returns of a portfolio are then readily obtained by multiplying its exposures to risk factors with their simulated returns. Because risk factors tend to drive the returns of funds, idiosyncratic risk is largely unpredictable. Consequently, this approach provides reliable estimates of a portfolio's range of behaviour in a given regime.

In the case where a simple gaussian distribution is used, the simulated returns of a portfolio is obtained via the formula:

$$r_t^{sim} = \beta\left(\mu + \Omega^{1/2}\varepsilon_t\right)$$

where Ω corresponds to the covariance matrix between risk factors and $\varepsilon_t \sim N(0,1)$ to a random series drawn from a normal distribution and μ the factors' expected returns during the regime. We found that expected returns are significantly affected by the regime, and so are the correlations between factors. The difference between the minimum and the maximum value of the average correlation is roughly 15%. Such variations have an important impact on the shape of the generated trajectories. Note that since equity factors have a long history, regimes are defined over periods involving several thousands of days (about 3,000). This leads to the correlation coefficients to be highly significant (<1%) even for values around 0.05.

Regimes impact analysis for different types of funds

To examine the impact of regimes on different types of equity portfolios, we have formed seven portfolios by equal-weighting funds following distinct strategies. The instruments used to form these portfolios were selected from a database of 650 US-based funds denominated in US dollars with at least seven years of data. Each portfolio is composed of funds with a given keyword shown in their name: for instance, the Low Risk portfolio was formed by selecting all the funds with the keywords defensive, low volatility or low risk in their names.[6] Similarly, the funds used in the Value, Small Size and ESG portfolios were selected using the value, small and ESG keywords. The Tech and Energy portfolios are simply sector-based index trackers. The Tracker portfolio is an ETF replicating the performance of the S&P 500. We report the results in figure 6. The unconditional return of the strategies, that is, their performance over the full sample, are also reported for comparison's sake.

Because we measured the active performance, the very small performance figures reported for the Tracker correspond to the difference between the performance of the index and the replicating portfolio. It is often insignificant, although in some cases the regime significantly affects the portfolio's replication quality. The portfolio based on the energy sector has the highest volatility and tracking error, and therefore exhibits large active performance in high volatility regimes. It is also sensitive to oil prices, as expected.

The Small Size portfolio is also more volatile than the market and is very sensitive to credit events. The Low Risk portfolio performs best during market downturns and is sensitive to variations in short-term rates. For fundamental strategies, the regimes based on the performance of the associated risk factors are more impactful than macroeconomic ones. This means that forecasts on the performance of risk premia are indeed an important input, although they are less commonly used in practice. We also find that, even though the ESG portfolio is sensitive to changes in the oil price, it is

6. Active performance in annualised percentage points for different portfolios in regimes

Macroeconomic variable	Regime type	Direction	Tech	Energy	Low risk	Small size	Tracker ESG	Tracker	Value
Credit spread	Change	Down	4.62**	11.21***	-4.60***	10.85***	-1.79***	-0.09	5.28***
		Up	-2.45	-9.74***	4.12***	1.63	-0.74	0.14	1.36
	Level	Low	3.54**	3.67	-2.45**	1.22	-1.38**	0.01	0.07
		High	-1.05	-2.24	2.37**	7.88***	-1.58**	0.18*	5.15***
Dollar index	Change	Down	4.33**	-3.86	-1.38	5.12**	-2.86***	-0.09	1.44
		Up	-1.95	1.83	1.76	3.04	0.09	0.19	2.82*
Inflation	Change	Down	-2.48	-7.96**	3.98***	6.01***	-0.25	0.16	4.01***
		Up	4.02**	12.96***	-4.12***	7.57***	-1.71**	0.04	4.03**
	Level	Low	2.49	-6.12	-0.45	3.44	-1.17	-0.00	0.96
		High	0.73	7.92***	-0.53	8.87***	-0.16	0.01	5.13***
Long-term rates	Change	Down	-4.62**	-14.24***	6.71***	0.21	-1.18	0.11	0.90
		Up	2.81	20.44***	-4.13***	7.96***	0.33	0.27**	5.44***
Market index	Change	Down	-10.24***	-12.77***	10.25***	-12.15***	6.66***	0.58***	-4.29**
		Up	8.59***	9.50***	-6.68***	25.62***	-7.30***	-0.34***	11.71***
Market volatility	Change	Down	7.90***	4.55	-5.40***	13.74***	-4.83***	-0.21*	5.54***
		Up	-4.31*	-7.17*	5.26***	-8.16***	3.49***	0.45***	-3.30*
	Level	Low	4.98***	2.54	-2.89***	8.62***	-3.63***	-0.15*	3.51***
		High	-4.13	-6.81	4.51**	-3.07	2.37**	0.50***	-0.06
Oil	Change	Down	-3.40	-13.50***	5.33***	-0.39	-0.26	0.26*	0.57
		Up	4.34**	7.00*	-3.43**	10.05***	-1.91***	-0.14	4.50**
Short-term rates	Change	Down	-5.39**	-8.34**	5.72***	-0.59	-0.70	0.35***	1.69
		Up	5.52***	1.83	-2.64**	1.77	-0.34	0.01	-0.41
	Level	Low	1.02	-3.00	-0.36	1.72	-1.52*	0.13	1.07
		High	2.41*	0.99	-0.62	5.21***	-1.13*	0.03	2.43*
Time spread	Change	Down	2.01	-11.59***	1.86	-1.36	-1.40*	-0.08	-2.18
		Up	-0.90	7.76**	-0.81	4.14*	-0.66	0.32**	4.02***
	Level	Low	2.04	-6.81	-0.03	-2.19	-1.41*	0.11	-1.84
		High	-3.03*	7.77***	1.54	4.43**	-0.12	0.31***	4.69***
ERF Investment	Change	Down	14.63***	-24.55***	-4.72***	0.74	-3.25***	-1.25***	-7.60***
		Up	-13.45***	43.76***	5.17***	9.80***	1.20*	1.57***	16.43***
ERF Momentum	Change	Down	-11.14***	15.47***	2.87*	8.79***	0.37	0.84***	11.95***
		Up	10.03***	-18.90***	0.81	-7.40***	-1.46*	-0.34***	-8.85***
ERF Profitability	Change	Down	-14.28***	42.10***	4.12***	7.48***	-0.76	0.54***	12.56***
		Up	17.51***	-29.96***	-3.40**	-1.07	-1.40*	-0.16	-7.18***
ERF Size	Change	Down	8.40***	-23.28***	-0.25	-24.51***	-2.15***	0.16	-17.39***
		Up	-6.38***	37.50***	-0.52	42.22***	0.05	0.14	27.09***
ERF Value	Change	Down	18.43***	-37.56***	-1.85	-7.62***	-2.56***	-0.70***	-12.75***
		Up	-17.36***	53.19***	4.78***	9.73***	0.77	1.26***	17.74***
ERF Volatility	Change	Down	19.11***	18.51***	-12.99***	17.34***	-0.35	-0.53***	3.89***
		Up	-17.97***	-11.76***	16.86***	-9.52***	-0.34	1.07***	1.93
Full sample	Unconditional		0.34	-0.72	0.47	3.87***	-1.11***	0.12**	2.43***

Notes: The statistical significance of the performance with 1%, 5% and 10% thresholds is denoted by (***), (**) and (*).

6 The Low Volatility portfolio is comprised of: AQR Large Cap Defensive Style Fund, MFS Low Volatility Equity Fund.
The Value portfolio is comprised of: Delaware Ivy Value Fund, Victory Integrity Small/Mid-Cap Value Fund, Multi-Manager Value Strategies Fund, Crossmark Steward Values-Focused Small-Mid Cap Fund, Virtus NFJ Large-Cap Value Fund, Dunham Large Cap Value Fund, LSV Small Cap Value Fund, Natixis International Funds (Lux) I - Harris Associates U.S. Value Equity Fund, VY® Columbia Small Cap Value II Portfolio.
The Small Size portfolio is comprised of: Vanguard Tax Managed Small Cap Fund, Hartford Small Cap Growth HLS Fund, Victory Integrity Small/Mid-Cap Value Fund, PIMCO StocksPLUS® Small Fund, Delaware Ivy Small Cap Growth Fund, Fidelity Small Cap Index Fund, Crossmark Steward Values-Focused Small-Mid Cap Enhanced Index Fund, LSV Small Cap Value Fund, Praxis Small Cap Index Fund.
The ESG Tracker portfolio is comprised of: Amundi Index Solutions – Amundi S&P 500 ESG, Transamerica Large Core ESG Fund, LLB Aktien Nordamerika ESG (USD), Goldman Sachs US Equity ESG Portfolio, SSGA Lux SICAV - State Street US ESG Screened Index Equity Fund, DWS ESG Core Equity Fund.
The Tech portfolio is comprised of: Columbia Seligman Technology and Information Fund, Fidelity Select Enterprise Technology Services Portfolio, Goldman Sachs Technology Opportunities Fund, JNL/Mellon Capital Information Technology Sector Fund.
The Energy portfolio is comprised of: JNL/Mellon Capital Energy Sector Fund.
The Tracker portfolio is comprised of: Invesco S&P 500 Index.

relatively more sensitive to market movements because of its lower market beta.

Another observation from figure 6 is the insensitivity of many strategies to, eg, inflation or time spreads. Regimes affect strategies differently, and so a case-by-case analysis is indeed required to compare the impact of macro-economic regimes on a portfolio's performance.

As a final example, we examine the impact of regimes on two low carbon indices, the MSCI USA Value ESG Reduced Carbon Target Select index and MSCI USA Minimum Volatility ESG Reduced Carbon Target index. The chosen decarbonisation approach for these indices impacts their composition, and therefore their exposures to risk factors. Notably, the two indices exhibit significantly different exposures to the Utilities sector, and in turn, to long-term interest rates. Based on the conditional simulation with respect to long-term rates, their exposures, on average, translate into very different annualised conditional active returns. For example, the low carbon value index generates a positive conditional active return in an up regime, whereas the low carbon minimum volatility index has the opposite behaviour, generating a negative return. The conditional active returns can be seen as a more intuitive and comprehensive alternative to traditional sensitivities to macro variables. Therefore, combining the two offsetting indices into an equally weighted portfolio would lead to an overall mitigated conditional active return. Our further research will explore this topic in more detail and aim to incorporate conditional simulations in a portfolio allocation framework.

Conclusion

The use of macroeconomic forecasts is a common input in investment processes. However, academic research on the impact of macroeconomic regimes has focused on isolating the effect of various economic variables on equity performance, whereas some important properties of macroeconomic regimes in the context of investment processes, such as their relevance, stability or robustness in- and out-of-sample, were scarcely studied.

We have considered previously studied macroeconomic variables and regimes and found that the returns of equity portfolios in these regimes have distinct statistical properties compared to long-term returns. Also, we found that these statistical features are stable, and robust out-of-sample. These properties are in fact desirable in the context of investment processes, as robustness and stability imply the possibility to benefit from forecasts and more reliable simulations.

We have shown that although the impact analysis of macroeconomic regimes on a portfolio are often hindered by the shortness of historical tracks, linear models with long-term equity risk factors allow the extrapolation of long-term returns quite efficiently. The precision of these extrapolations suggests that funds with high R-squared have stable exposures to risk factors. We have also determined that about five years of historical returns almost achieved the best precision.

Finally, we showed that funds following different strategies did exhibit significant variations of relative performance in the regimes studied. This last observation helps us to understand how active exposures affect sensitivity to macroeconomic regimes, and hence should be considered in the context of macroeconomic forecasting and eventually portfolio allocation.

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Active risk diversification helps stabilise tracking errors: empirical evidence from US equity ETFs

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In this study, we estimate the level of risk diversification for a universe of US equity ETFs and observe the benefits of diversification for budgeting of active risk relative to a cap-weighted benchmark.

We introduce a measure of concentration risk, inspired by the Equal Risk Contribution (ERC) concept, which relies on factor-related risk contributions and only requires knowledge of historical returns.

We then use this concentration measure to highlight the impact of diversification on tracking error stability and find conclusive empirical evidence that US equity ETFs with a diversified set of systematic active risk contributions have a more stable tracking error.

These results suggest that investors seeking a more predictable tracking error for active risk budgeting purposes may benefit from selecting ETFs that have a strong level of risk diversification.

Nearly 50 years ago, Jack Bogle created the first index mutual fund, now known as the Vanguard 500. This transparent, low-cost passive investment product provided investors with exposure to the returns of the Standard & Poor's 500 market capitalisation weighted (CW) index, laying the foundation for the emergence of exchange-traded funds (ETFs), a vehicle that allows a portfolio of stocks to be traded on stock exchanges as a single stock (Arnott and Sherrerd [2022]). The first ETFs were designed as alternatives to futures for market participants unable or unwilling to trade on futures exchanges and later evolved to become suitable long-term investments that passively tracked CW indexes.

Today, there are ETFs that track a non-CW index (including sector ETFs and smart beta ETFs) and ETFs that follow an active management strategy. Each type of non-CW equity ETF has exposure to systematic equity risk factors other than the overall market factor (eg, either fundamental risk factors or industry risk factors). Actively managed ETFs also presumably include specific (non-systematic) risk linked to the manager's skill. Equity investors now have access to a large variety of passively managed smart beta and actively managed ETFs: At the end of June 2022, 18% of equity ETF instruments globally were following a passive smart beta strategy and 14% were actively managed.[1]

Investors looking to allocate capital away from a CW ETF to a non-CW ETF may reasonably want to understand the relative risk from the latter (we designate this relative risk as 'active risk' for the remainder of the article). Generally, the decision to invest in a non-CW ETF will be implicitly compared to the optically safer choice of investing in a CW ETF because the latter's value is well understood by investors.

The metric traditionally provided by active managers or promoters of non-CW indices to inform an investor's assessment of active risk is the tracking error (TE), estimated from the past returns of an ETF. Investors therefore translate their combined levels of risk appetite and trust with respect to a non-CW investment strategy into a TE risk budget they are willing to tolerate. Unfortunately, an empirically estimated TE is by design a backward-looking risk metric that may not always be a good estimator of future TE, especially if the investment strategy followed by the non-CW ETF generates large variations of TE. Therefore, investors need to carefully analyse the make-up of the observed TE to assess their comfort in relying on a backward-looking risk measurement for active risk budgeting. Our intention in this article is to propose an ex-post risk analysis methodology that will help investors make such an assessment for non-CW ETFs.

Rigorous risk analysis ought to identify and separate systematic risk from non-systematic (specific) risk, because the former is more persistent, can be somewhat quantified and cannot be fully diversified away. This approach is equally valid for investors trying to analyse active (relative) risk. For the equity asset class, the standard industry practice is to describe the systematic risk of equity portfolios using a common set of factors. Provided these systematic factors explain most of the equity portfolios' prevailing risks, it may be possible for a risk model to break down relative risk (and therefore

1 https://etfgi.com/

TE) into individual factor-related risk contributions. Institutional investors commonly use the concept of *risk contribution* in order to budget risk in accordance with the constraints of their mandate, and our study aims to help investors with active risk budgeting when reviewing a non-CW ETF – the more ex-post evidence one has about the stability of an ETF's TE, the easier it is to determine whether an appropriate amount of capital was allocated to the ETF relative to risk budgeting.

The question of how investors should use the relative risk contributions obtained via the factor risk model may be intuited. In portfolio theory, diversifying the sources of uncertain returns leads (all else being equal) to lower portfolio risk and smaller variations in returns. Applying this insight to volatility tells us that diversifying the sources of volatility should lead to smaller variations in portfolio volatility. In other words, a diversified set of active risk contributions should be associated with smaller variations in TE.

Maillard, Roncalli and Teïleteche (2010) showed that diversifying risk contributions is a useful way to construct portfolios. It addresses some issues with two other portfolios commonly used by practitioners, the naïve equal-dollar (1/N) portfolio and the minimum variance (MV) portfolio. The 1/N portfolio often puts too much risk in volatile assets, while the MV portfolio is often concentrated in the assets with the lowest ex-ante volatility, leading to unstable results. The Equal Risk Contribution (ERC) portfolio can be seen as a risk-aware 1/N portfolio, aiming for a balanced risk budget. It tends to produce improved out-of-sample results compared to the two other portfolios, especially when the portfolio constituents are not strongly correlated. The ERC portfolio is overall less volatile than the 1/N portfolio and less concentrated than the MV portfolio, therefore carrying smaller tail risk (VaR, drawdown).

Roncalli and Weisang (2012) transpose this idea to a factor-based framework, which has fewer, less correlated sources of risk. They find that the factor-ERC portfolio has similar attractive properties in terms of tail risk. These properties are particularly useful for risk budgeting and the ERC portfolio therefore serves as a reliable benchmark when evaluating the stability of a portfolio's risk. Applying the concept to active risk in non-CW ETFs leads to the following insight: non-CW ETFs whose TE is *diversified* in terms of factor active risk contributions are expected to exhibit a more stable TE. Conversely, non-CW ETFs with a *concentrated* TE are expected to exhibit a more volatile TE, making the active risk budgeting exercise more challenging.

In a recent research paper (see Herzog, Jones and Safaee [2023] for more details), we test this insight for the US equity ETF market by proposing an ex-post methodology to assess active risk diversification based on the proximity to an ERC portfolio of active risks. Our analysis does not seek to uncover an ex-ante metric that would have attractive out-of-sample predictive power on the stability of future TE, but rather aims to verify that risk diversification and stable TE work hand in hand, thus providing evidence that one way of stabilising TE (for active risk budgeting purposes) is to maintain diversification of active risk contributions. Importantly, our methodology does not require knowledge of an ETF's holdings.

Dataset

Our study relies on a database of ETFs provided by Trackinsight[2], a leading provider of ETF markets data and analytics. The universe consists of 862 ETFs domiciled in the US and pursuing a US 'Delta One' equity strategy, representing approximately $3.8trn in assets under management (AUM). Our study excludes ETFs exposed to other assets classes and equity ETFs involving leverage or non-linear/option-based strategies. The analysis uses weekly total returns data covering the five-year period from October 2017 to September 2022. The sample dataset only includes the subset of ETFs reporting a full five years of returns with no material gaps.

Our study analyses ETFs that carry material risk relative to a CW benchmark. Accordingly, ETFs which track or loosely track a broad, cap-weighted benchmark are excluded. The analysis excludes all ETFs that exhibit a TE less than 2% relative to the SciBeta United States Cap-Weighted index (comprised of the 500 largest US stocks and whose returns are therefore similar to the S&P 500 index).[3] We determine the TE lower bound of 2% by identifying the types of ETFs expected to fall within the scope of the analysis (namely sector, smart beta and actively managed ETFs) and empirically determining a lower bound for each group using 20 years (2002-22) of historical data. Selecting 2% as the lower bound of TE for the inclusion of ETFs for analysis results in a universe of 488 ETFs representing AUM of $2.3trn.

Risk model

The remaining ETFs contain a material amount of risk relative to the CW benchmark, measured by their TE. To analyse the active risk of an ETF, our study uses a new risk model (Vaucher [2023]) that builds upon the Integrated Principal Component Analysis (IPCA) model (Kelly, Pruitt and Su [2019]) in order to combine time-series, cross-sectional and statistical approaches. Multivariate betas are the traditional measures of systematic risk because they capture the covariances of a portfolio relative to systematic risk factors. Put simply, betas are covariances and covariances are risks. However, the implementation challenges that multivariate betas create should not be underestimated. Multivariate betas largely depend on a chosen list of factors, the number of which is constrained to avoid collinearity issues that may affect the decomposition of systematic risks. A common workaround is the use of principal component analysis (PCA) and implicit factors, but this obscures the economic meaning of each factor, reducing the ability to easily amend unwanted risk exposures via allocation actions.

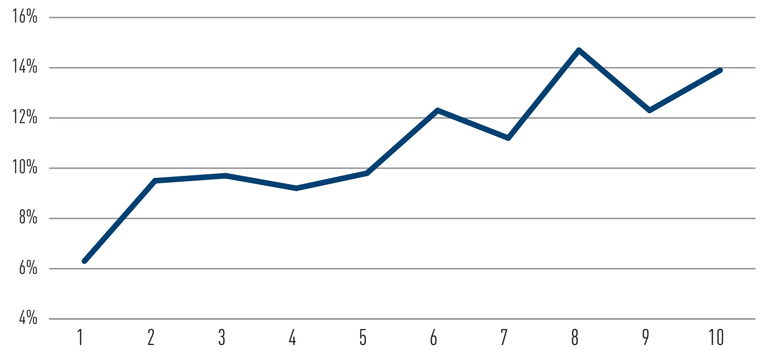
In response to these challenges, a risk model with the intuitive appeal of a time-series approach, the flexibility of a cross-sectional approach, and the parsimony of a statistical approach is used to carry out risk analysis. The first step involves scanning instruments through the intuitive lens of a fundamental time series model, using seven fundamental time series risk factors and then, separately, 10 sector-based risk factors. The resulting 17 estimated betas (factor exposures) represent a full risk identification card that is fed into the cross-sectional engine, which in turn, appropriately disentangles the informational overlaps between fundamental betas and sector betas. However, the cross-sectional disentangling does not address the fact that there are arguably too many betas in the risk identification card, and the model is likely overspecified. That is why the cross-sectional engine also includes a critical feature designed to avoid overspecification (similar to what PCA-based statistical models do) and reduce (behind the scenes) the dimensionality of the model. This ensures there is no 'double counting' and makes the model's results more robust. Systematic risk can then be decomposed into additive risk contributions that are reallocated back to the set of economically intuitive fundamental and industry factor exposures. The sum of these 17 risk contributions equals the total systematic volatility. A notable advantage of this model is that it requires

2 https://www.trackinsight.com/
3 https://www.scientificbeta.com/

1. The R-squared pertaining to the universe of ETFs used for analysis

	R^2
25th percentile	93%
Mean	95%
Median	97%

2. Median systematic TE conditional on a CRM decile



Note: The horizontal axis represents the deciles of ETFs measured by CRM. The first decile represents ETFs which are the least concentrated (ie, most diversified) in terms of factor-based active risk diversification while the tenth decile represents ETFs which are the most concentrated. Each decile comprises approximately 48 ETFs. The vertical axis represents the median value of the systematic TE for each decile.

only fund-level time-series data instead of more complex stock-holdings data.

We measure the risk model's performance by computing the R-squared for each ETF in the study's universe. If an ETF has a large proportion of unexplained risk, shown by an R-squared of less than 75%, it is excluded from the analysis. This process removes an additional 15 ETFs. Figure 1 shows the model's precision at different levels for the remaining universe of ETFs.

The levels of R-squared reported in figure 1 confirm the risk model's ability to explain risk with a sufficiently high level of precision for computing the active risk contributions in the ETFs.

Measuring active risk concentration in non-CW US equity ETFs

The risk model allows us to produce a decomposition of systematic active risk into individual factor-based active risk contributions, with a total of 17 systematic active risk contributions that add up to the systematic (ie, explained by the model) portion of the TE. We do not opine on whether and how specific (unexplained) risk contributes to the concentration or the diversification of an ETF.

We use this decomposition to construct a measure of concentration, which we call Concentration Risk Measure (CRM), which can identify the non-CW ETFs whose TE are expected to be stable because of their proximity to the ERC portfolio. The CRM measure is defined as:

$$\text{CRM} = \frac{\sqrt{\sum_{i=1}^{17} \text{Active Risk Contribution}_i^2}}{\text{Systematic TE}}$$

where *Systematic TE* is the systematic portion of the ETF's TE, equal to the sum of the 17 active risk contributions.

The CRM qualifies the distance (in terms of normalised active risk contributions) between an ETF and its corresponding hypothetical ERC portfolio. The ERC portfolio is designed to have a total risk equal to the systematic portion of the ETF's TE. The higher the CRM value for an ETF, the more concentrated the ETF is and the greater the expected TE instability.

The CRM can also be interpreted in terms of risk, noting that

$$\frac{1}{CRM^2}$$

is the effective number of active risk contributions for the ETF. Diversification reduces portfolio volatility by a factor of

$$\frac{1}{\sqrt{N}}$$

in a hypothetical portfolio of N uncorrelated assets sharing the same mean and volatility. This interpretation infers that CRM is homogeneous to volatility and a proxy for the diversification-related volatility reduction factor created by a given portfolio.

Benefits of diversification for active risk budgeting in US equity ETFs

We use the CRM to analyse the universe of non-CW US equity ETFs and highlight the benefits of diversification of active risk contributions.

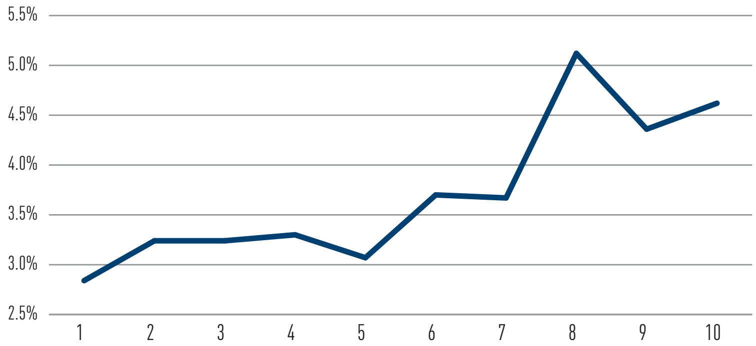
First, we identify whether the level of an ETF's CRM impacts its level of systematic TE. Figure 2 shows the systematic TE of ETFs in the universe conditional upon different levels of concentration as measured by CRM. The trend indicates that systematic TE increases with CRM: the median systematic TE is approximately 6% in the lowest decile and approximately 14% in the highest decile. This is consistent with the view that the ERC portfolio is relatively low risk and that factor-based risk diversification reduces portfolio risk. Median values are represented in figure 2, rather than averages, to mitigate outlier effects and account for the fact that risk contribution concentration is not the only factor influencing an ETF's systematic TE.

We analyse the variations of the TE over time to determine whether the stability of TE is dependent on the level of an ETF's risk diversification. TE is computed for six-month daily rolling windows across the five-year period using daily returns data, generating a time series of short-term TEs.

To determine the impact of CRM on the level of TE stability of non-CW ETFs, we calculate the median value of sample standard deviations of the six-month daily rolling TE's time series. Results are plotted against CRM deciles in figure 3. The upward sloping curve indicates that concentration of active risk contributions is associated with greater variability in TE: the median value of the TE standard deviation for the most concentrated decile is more than 1.5x greater than that of the most diversified decile. This aligns with the ERC portfolio's behaviour and reduced kurtosis relative to other heuristics (see Maillard, Roncalli and Teïleteche [2010]).

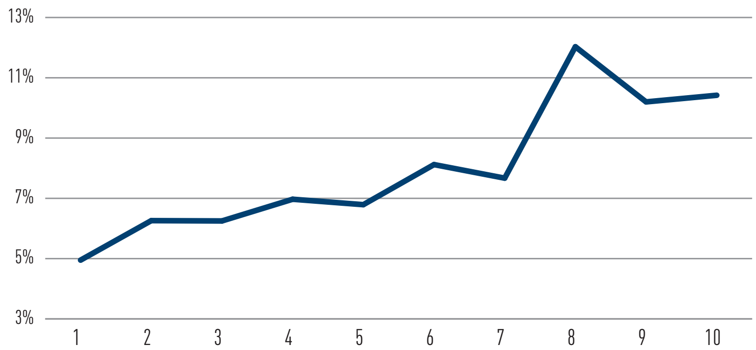
We then examine the relationship between active risk concentration and extreme moves in TE. The historically highest 5% of the six-month rolling TEs represents the tail of the TE's time-series distribution, acting as a measure for extreme active risk. Figure 4 shows the median of the difference between the 5% quantile of TEs and the average of TEs, plotted against CRM deciles. The same upward sloping pattern as the two previous exhibits (with the most concentrated decile displaying roughly twice the extreme active risk of the most diversified one) confirms the consistency of the empirical results with the expected properties of portfolios diversified across active risk contributions, namely their reduced active tail risk and consequentially a more stable TE.

3. Median standard deviation of six-month daily rolling TE conditional on a CRM decile



Note: The horizontal axis represents the deciles of ETFs measured by CRM. The first decile represents ETFs which are the least concentrated (ie, most diversified) in terms of factor-based active risk diversification while the tenth decile represents ETFs which are the most concentrated. Each decile comprises approximately 48 ETFs. The vertical axis represents the median value of the time-series standard deviation of six-month daily rolling TEs for each decile.

4. Median value of 5% historical quantile of six-month daily rolling TE minus average of six-month daily rolling TE, conditional on a CRM decile



Note: The horizontal axis represents the deciles of ETFs measured by CRM. The first decile represents ETFs which are the least concentrated (ie, most diversified) in terms of factor-based active risk diversification while the tenth decile represents ETFs which are the most concentrated. Each decile comprises approximately 48 ETFs. The vertical axis represents the median value of the difference between the 5% historical quantile of six-month daily rolling TE and the time-series average of six-month daily rolling TEs for each decile.

Conclusion

Using only historical returns, our equity risk model combines the benefits of fundamental and statistical approaches and explains a large portion of US equity ETFs risk, allowing an assessment of the concentration of systematic active risk contributions in US equity ETFs whose investment strategy deviates from a cap-weighted benchmark. Intuition, supported by the academic literature on the Equal Risk Contribution portfolio, indicates that non-cap-weighted portfolios exposed to a diversified set of systematic active risk contributions should also have a more stable tracking error. The US equity ETF market provides conclusive empirical evidence of this effect, indicating that investors who wish to budget their active risk more accurately may do so by primarily selecting well-diversified non-cap-weighted ETFs. A diversified TE budget not only promises robustness, but also signals a prudent risk-taking by some managers of non-CW ETFs. These managers have likely made more balanced bets compared to managers with concentrated exposures via a small number of risk factors. On average, winning managers do not repeat their outperformance, so opting for a concentrated TE may, in the long-term, lead to disappointing risk-adjusted returns.

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Do climate-related exclusions have an effect on portfolio risk and diversification?

A contribution to the 'Article 9' funds controversy

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Out of 161 funds reporting a 'sustainable investment objective' in accordance with the European sustainable financial disclosure regulation (article 9), 50 contain stocks of companies involved in coal, oil and gas or aviation. These stocks represent on average 2.8% of the funds' invested capital.

Excluding these stocks with a naive (pro rata) reallocation leads to an average tracking error of 0.53% with the original portfolio. Sector deviations occur mainly in the 'Energy' and 'Utility' sectors. In terms of fundamentals, exclusions increase exposure to higher 'quality' stocks, whereas exposure to 'investment' and 'value' stocks is slightly reduced.

Excluding these stocks with an optimised reallocation technique further reduces the average tracking error to 0.42%, while also reducing fundamental differences between the original and optimised portfolio. These results suggest that excluding climate controversial stocks has overall a limited impact on the risk profiles of the funds.

Introduction

With the increase in funds claiming to be 'responsible', 'sustainable' or 'impact', the regulators are clarifying the scope of these funds to prevent 'financial greenwashing'. As part of its Action Plan for Sustainable Finance, the European Union (EU) now imposes, through its Sustainable Finance Disclosure Regulation (SFDR), reporting requirements that depend on the ambition of the funds: funds that claim to have a 'sustainable investment objective' must comply with 'Article 9' requirements, while funds that highlight environmental or social characteristics as part of a broader investment strategy must comply with 'Article 8' requirements. These two categories of reporting requirements have promptly been considered by the market as 'labels' associated with the funds, Article 9 funds being the most ambitious in terms of extra-financial impact. However, the reporting requirements of the SFDR leave room for interpretation of the definition of a 'sustainable' investment, as well as flexibility with respect to the levers to be used to achieve the 'sustainable investment objective': exclusions, reallocation, shareholder engagement.

The flexibility left to managers in the implementation of impact strategies is at the root of a significant controversy concerning funds considered as 'Article 9'. In November 2022, two investigative journalism platforms – Follow the money and Investico – published the Great Green Investment Investigation (GGII) in collaboration with a dozen European media.[1] They revealed that nearly half of the 838 European 'Article 9' funds had invested in companies that are involved in the fossil fuels and aviation sectors and that the journalists identified as significant contributors to global warming due to their lack of 'a credible climate strategy'. Following this investigation and other controversies, 40% of the initial 'Article 9' funds – many of these being passive funds tracking EU Climate Transition and Paris-Aligned benchmarks – were voluntarily downgraded to 'Article 8' by the fund managers at the end of 2022, according to Morningstar.[2]

Several reasons may explain the holding of these controversial stocks in sustainable portfolios: data discrepancies in the assessment of their environmental impact, a willingness to engage with the company as a shareholder with the objective of improving their practice, or a strategy of gradual exclusion. Whatever the reason, a question that arises sooner or later for the asset manager is to know what would be the

1 The main results of the investigation are available at: https://www.ftm.eu/green-investments (visited September 2023).

2 Source: https://www.sustainalytics.com/esg-research/resource/investors-esg-blog/sustainable-investments-definition-across-eu-regulations-still-unclear (visited September 2023).

impact of excluding these controversial stocks on the performance and risk profile of the fund.

There is no consensus on the existing literature whether the integration of environmental, social and governance (ESG) criteria in investment funds affects the financial performance of the funds (Friede, Busch and Bassen [2015]). One of the reasons for this lack of consensus is the broad spectrum of practices that fall under 'integration' of ESG criteria. Among these different practices, several studies have investigated the effect of the exclusion of stocks, with mixed results (eg, Khajenouri and Schmidt [2021]; Capelle-Blancard and Monjon [2014]). Even when focusing on the exclusion of fossil fuels, the effect on funds' performance remains uncertain: Henriques and Sadorsky (2018) find negative effects while Trinks et al (2018) find no difference and Hunt and Weber (2019) find positive effects. Our study aims to contribute to this literature by focusing on the effects of exclusion on risks rather than short-term performance: what would be the impact of excluding stocks associated with climate change on the risk profile of funds that have a 'sustainable investment objective' ('Article 9') funds? The risk profile of a fund is responsible for its long-term performance patterns and should therefore be a primary concern for managers.

Data and model

As there is no consensus on the definition of sustainable funds, we present in this section the criteria used to build our sample of funds, as well as the ESG data used to identify controversial stocks related to climate change. We finally present the risk metrics used to study the effects of exclusions on fiduciary liability.

Sample of sustainable funds

To avoid defining a new subjective criterion for considering a fund to be sustainable, our sample is composed of funds that meet the more stringent criteria of the SFDR, ie, funds that have a 'sustainable investment objective' and must therefore comply with 'Article 9' requirements.[3] These sample criteria are in line with those used by the GGII but differ in the observation date: our sample list has been extracted as of July 2023 while the sample list of the GGII has been extracted as of the 30 June 2022. Following – among other things – the controversies that arose in the wake of the GGII, around 40% of Article 9 funds were reclassified as Article 8 by the end of 2022. We can therefore expect the results obtained from our sample to differ from those obtained by the GGII as a result of this wave of reclassification.

We excluded funds with historical tracks of less than a year, as well as funds with more than 1% of their holdings in emerging countries. Also, we only considered funds whose composition is available and accounts for at least 85% of the capital invested. Our sample thus contains 161 'Article 9' funds that contain a total of 2,362 stocks.

Criteria for climate-related exclusion

To identify the controversial companies that should therefore be excluded, we rely as far as possible on the same criteria and data as the GGII. We used Bloomberg's sector classification 'airlines' and 'airport development/maintenance' to identify companies involved in the aviation sector, and Urgewald's[4] Global Coal Exit List (GCEL) and Global Oil & Gas Exit List (GOGEL) to identify companies involved in the coal, oil and gas sectors. The GCEL is a list of 2,799 companies involved in coal production[5], based on a database that covers the entire thermal coal value chain. Similarly, the GOGEL is a list of 901 companies – responsible for 95% of the world's oil and gas production – operating in upstream and/or midstream subsectors.[6]

Risk profile of the funds

To assess the impact of exclusions on the funds' risk profile, we analyse several key indicators. First, we estimate the tracking error between the screened and the initial funds[7] using a sample covariance matrix normalised with the methodology proposed in Ledoit and Wolf (2003). We also measure the impact of exclusions on sectors weights[8], as well as exposures to traditional risk factors. For the latter, we use the five-factors model of Fama and French (2015), and obtain factor exposures (or betas) by estimating the following regression on the last five years of daily returns

$$R_{it} = \beta_{Mi} R_{Mt} + \beta_{SMB,i} SMB_t + \beta_{HML,i} HML_t + \beta_{RMW,i} RMW_t + \beta_{CMA,i} CMA_t + \varepsilon_{it}$$

where R_{it} represents the return of the ith fund, the returns of the local market factor are denoted by R_{Mt} and ε_{it} is the error term. There are different sets of risk factors for every geographical region, and hence exposures are evaluated with the set corresponding to the region where the company is domiciled, which can be any of North America, Europe, Japan or Asia Pacific ex-Japan. Exposures to the SMB (small minus big) and HML (high minus low) factors are associated with small stocks and good-value stocks, respectively. Stocks exposed to the RMW (robust minus weak) factor are associated with high-quality companies, whereas those exposed to the CMA (conservative minus aggressive) factor with companies that invest conservatively.

Exclusion methods

We apply two methods to perform exclusions from the funds' portfolio. The first, that we call naive, is an exclusion followed by a pro-rata reweighting of the portfolio remaining stocks.[9] This method assumes that an investment manager sells the controversial positions and reinvests the proceedings in the remaining equity positions proportionally to their initial weight.

The second method is based on a tracking error minimisation between the original portfolio and the new portfolio that does not contain the excluded stocks. The new portfolio is therefore the solution to the minimisation program:

$$w_{new} = \arg\min_w \left(w - w_{old}\right)^T \Omega \left(w - w_{old}\right)$$

Here the covariance matrix is the same sample covariance matrix normalised with the methodology proposed in Ledoit and Wolf (2003) that we use to measure the ex-post tracking error.[10] Here portfolios are long-only and their budget constraint is set so that the old and new portfolio have the same amount of capital invested. The resulting portfolios correspond to the action of an investment manager who would sell the controversial positions and reinvest the proceeds in a way that reduces the impact of the exclusions on the risk of the portfolio. It will therefore favour re-investments in stocks with risk profiles as close as possible to the excluded ones.

3 Data from Morningstar.
4 Urgewald is a German non-profit organisation whose objective is to establish environmental and social standards for the international finance industry.
5 As of April 2023.
6 As of April 2023.
7 The tracking error is computed using daily returns over five years. Missing returns are replaced by zero, which does not alter the calculation since the covariances used to calculate the tracking error are zero.
8 We use the Refinitiv Business Classification for 13 economic sectors.
9 During this reallocation, however, we keep the equity portion of the fund constant, so that the tracking errors and factor exposures are consistent to the funds' behaviour. If, for example, a fund has 85% equity and 15% must be excluded, this 15% will be distributed in proportion to the remaining 70% of equity stocks, but in such a way that the sum of equity is always equal to 85%.
10 All prices are in US dollars.

Results

Despite the wave of reclassification from Article 9 to Article 8 funds, almost a third of our fund sample still contains controversial climate-related stocks. We show that excluding these stocks would have small effects on the risk profiles of the funds and that these effects can be reduced by optimising the reallocation.

Investments in controversial climate-related stocks

In our sample of 161 funds, 50 funds contain stocks whose underlying companies are involved in at least one of the three climate-related controversial activities – coal, other fossil fuels and aviation (representing 60 different stocks). While being one of the most controversial activities, involvement in coal is the most frequently encountered criterion, both in terms of number of stocks and number of funds (figure 1).

From a regional perspective, the companies involved in the controversial activities are mainly located in Europe and North America (figure 2), which is in line with the region distribution of the funds in our sample (nearly half are based in Europe and over a third in the US). In proportion, controversial stocks represent 2.3% of the number of stocks in our sample based in Europe (in line with North America), while this figure is approximately twice as large for Asia-Pacific.

When it comes to weights into funds, the share of controversial stocks in our sample of sustainable funds is on average 2.82%. However, this number is driven by three funds with extreme values: 50% of the funds have less than 1.60% of their weight invested in controversial stocks (figure 3). The three funds with the highest share of controversial stocks are infrastructure investment funds that have committed to investing in infrastructure companies aligned with sustainability objectives for at least a given share of their assets. This suggests that the remaining share of the assets are not subject to sustainable criteria.

Effects of exclusion on tracking error

Excluding stocks with a naive reallocation leads to a relative tracking error (between the fund after exclusion and the fund before exclusion) of 0.53% on average (the median is 0.32%), which is low. The reallocation technique based on tracking error minimisation slightly reduces this number, with an average ex-post relative tracking error of 0.40% (the median is 0.23%). The tracking error is on average proportional to the total weight of excluded stocks (figure 4). For some

1. Controversial stocks

	Involved in coal	Involved in oil and gas	Involved in aviation	Involved in controversial activities	Total
Number of stocks	23	18	21	**60**	2,362
Number of funds	36	22	22	**50**	161

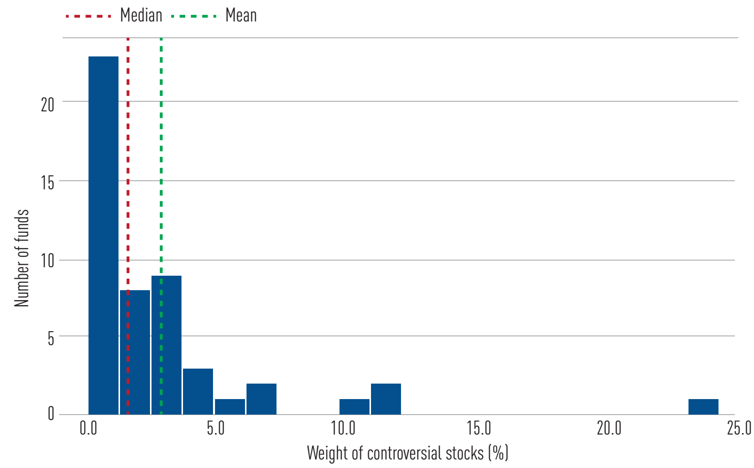
Note: some stocks are excluded for multiple controversial activities.

2. Number of controversial stocks by region

	Involved in coal	Involved in oil and gas	Involved in aviation	Involved in controversial activities*	Total
Europe	*5*	*11*	*10*	*25 (2.3%)*	*1,079*
North America	*14*	*3*	*4*	*21 (2.4%)*	*860*
Asia-Pacific	4	2	2	8 (5.8%)	138
Japan	2	3	2	6 (2.1%)	285

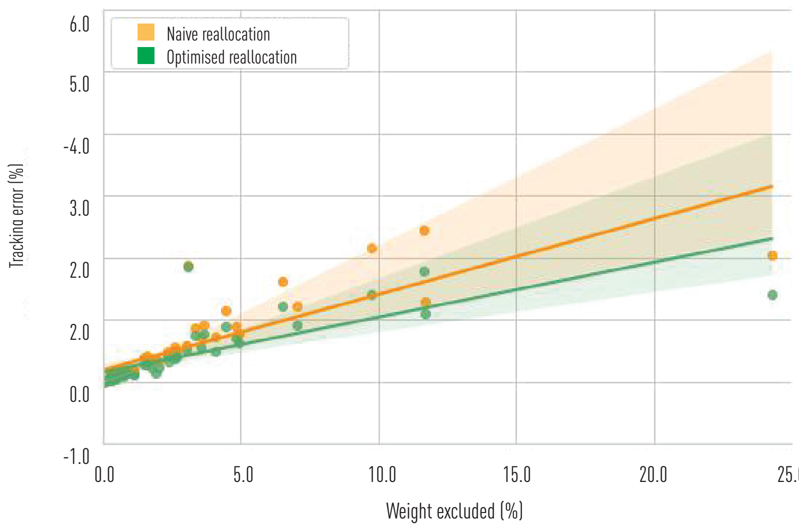
Note: *This figure is given in number of stocks and in proportion to total number.

3. Distribution of weights of controversial stocks in funds



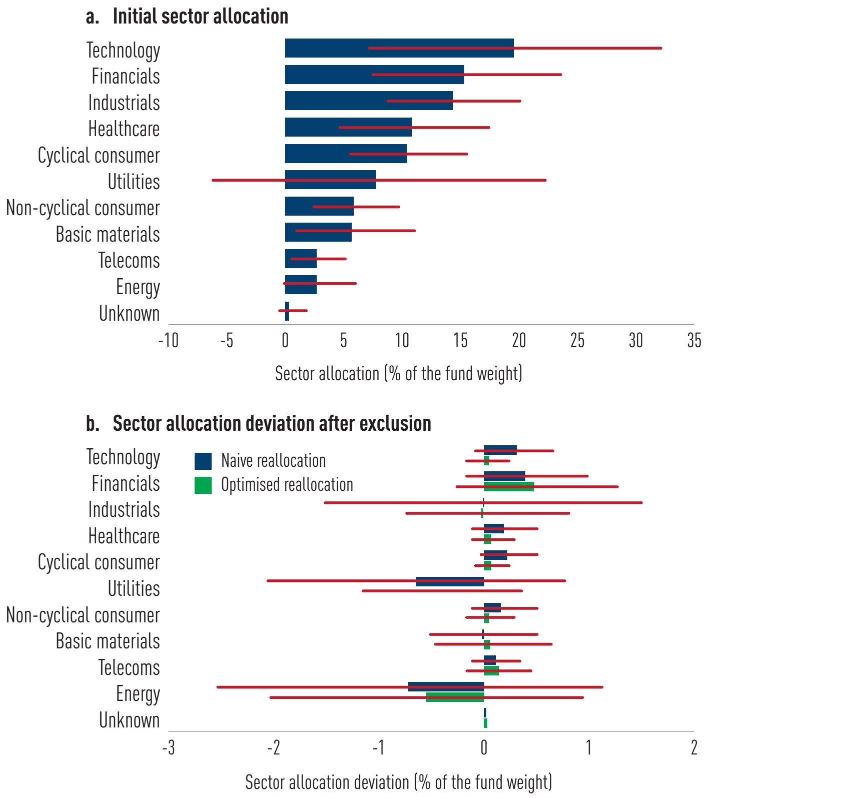
Note: the sample is made of the 50 funds holding controversial stocks.

4. Effects of exclusion on tracking error



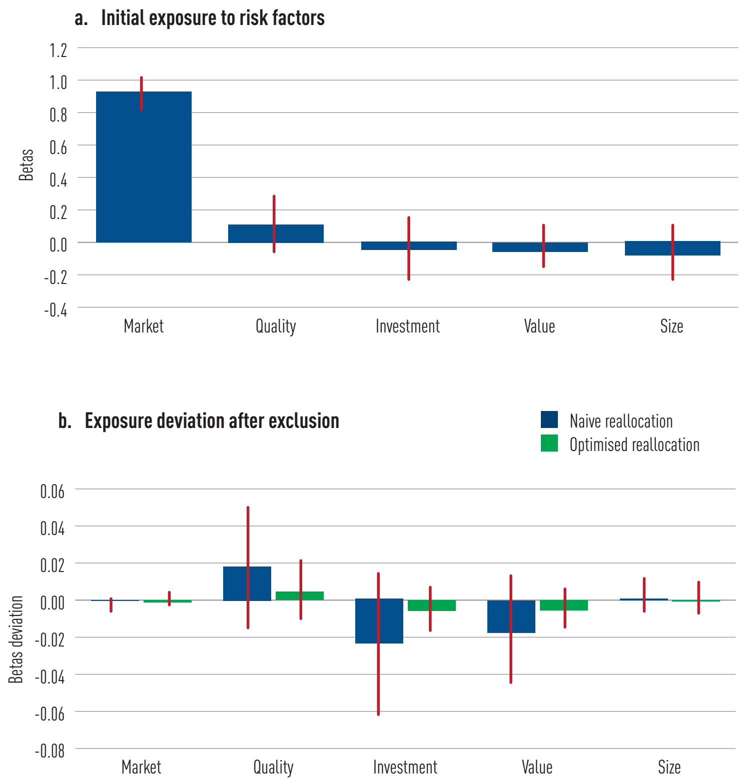
Note: the sample is made up of the 50 funds holding controversial stocks. The two lines represent the linear regression model between the weight excluded and the tracking error, while the coloured areas represent the 95% confidence intervals for the regressions.

5. Effects of exclusion on sector allocation



Note: the sample is made of the 50 funds holding controversial stocks. The coloured bars represent cross-sectional averages while the horizontal lines represent cross-sectional standard deviations.

6. Effects of exclusion on exposure to risk factors



Note: the sample is made of the 50 funds holding controversial stocks. The coloured bars represent cross-sectional averages while the vertical lines represent cross-sectional standard deviations.

funds, excluding controversial stocks would induce a tracking error above 1.00%. In these cases, the optimised reallocation method is particularly efficient, as it produces much lower tracking errors than the naive method.

Effects of exclusion on sector allocation

The exclusion mainly leads to sector allocation deviations in the Energy and Utilities sectors (absolute deviations of respectively -0.72% and -0.65%, figure 5b), which is consistent with excluding companies in the fossil fuel industry. The result for the Industrials sector is less intuitive, as the average deviation is close to 0% while the sector is the one highly represented in excluded stocks (23/60, through aviation). This is mainly due to a compensation effect: aviation, which represents a small share of the Industrials sector is excluded but the remaining allocation to the Industrials sector increases during the reallocation process as the sector represents an important share of the initial allocation (figure 5a).

Compared to the initial allocation, the most important relative deviation concerns the Energy sector with the sector weight falling on average from 2.66% to 1.94% (which represents a relative deviation of 27%). The optimisation does not reduce overall sector deviations: the reduction of deviation for the Energy and Utilities sectors is compensated by an increase in deviation for Financials, Telecoms and Basic materials sectors.

Effects of exclusion on exposure to risk factors

The exclusion with naive reallocation increases funds average exposure to the Quality (RMW) factor (from 0.11 to 0.13) and decreases average exposure to the Investment (CMA) and Value (HML) factors (from -0.05 to -0.07, figure 6). These results can be explained by the factor exposure of the controversial stocks and their sectors. The 18 companies involved in 'oil and gas activities' and the 21 companies involved in 'aviation' have for example a significant negative exposure to the Quality factor. Excluding these companies therefore leads to an increased exposure of funds to this factor. Similarly, the companies involved in the three controversial activities have a strong positive exposure to the Investment and Value factors, therefore leading to a decreased exposure of funds to these factors after exclusion.

From a risk management perspective, these deviations are not trivial. However, the optimisation method significantly limits the exposure deviation to these factors (figure 6b).

Conclusion

This article contributes to the literature on the effects of excluding controversial stocks on the funds' financial performance (Henriques and Sadorsky [2018]; Trinks et al. 2018 and Hunt and Weber [2019]). In order to be closer to the asset managers' concerns and constraints, we propose to shift our focus from performance to risk profile. We seek to understand whether fiduciary liability might explain why asset managers have chosen to hold these controversial stocks in their sustainable portfolios.

Following the 2022 investigation published by a consortium of a dozen European media, we analyse for 161 funds that have a 'sustainable investment objective' according to the European sustainable financial disclosure regulation (Article 9) the effects of excluding stocks involved in coal, fossil fuels and aviation on the funds' tracking error, sector allocation and exposure to the Fama and French (2015) five factors.

As of 2023, we show that of over 161 funds that have a 'sustainable investment objective' according to the European sustainable financial disclosure regulation (Article 9), 50 still contain stocks of companies involved in coal, oil and gas or aviation despite the 2022 wave of reclassification from Article 9 to Article 8.

The exclusion of these stocks even with a naive reallocation has a limited effect on the tracking error and sector diversification of the funds. The results are consistent with those from Trinks et al (2018)'s long-term analysis, ie, the average impact on the tracking error of excluding climate-related stocks[11] is small but increases with the weight of excluded stocks. In some cases, we show that exclusion causes nontrivial deviations in exposure to the Quality, Investment and Value risk factors. However, we show that a risk minimisation method can significantly reduce these deviations.

Finally, our results suggest that holding these stocks in sustainable funds is not justified from a risk perspective. In order to guarantee the credibility of these funds, it therefore seems essential that asset managers justify the holding of these stocks, either by differences on the assessment of their belonging to controversial sectors (data discrepancy), or by a shareholder engagement policy aimed at improving the practices of the underlying companies.

However, these results should not be generalised to all exclusion practices and to all funds: they concern specific climate-related criteria as well as funds claiming a sustainable objective. One avenue of research could be to extend the analysis of the effects of exclusion on risk metrics to other exclusion criteria, including social and governance issues on a broader universe of funds. In these cases, it will be particularly interesting to disentangle the impact on the tracking error due to the weight of excluded stocks - which is likely to be higher - from deviations in exposure to factors linked to exclusion, and from changes in the proportion of unexplained risk.

11 Trinks et al (2018) consider 'Coal', 'Oil and gas' and 'All fossil fuels' but not 'Aviation'.

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