

A Scientific Portfolio Publication

Attribution Analysis
of Greenhouse Gas Emissions
Associated with an Equity
Portfolio: A Comparison
of Existing Frameworks

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Abstract

Understanding the drivers influencing the greenhouse gas emissions associated with financial portfolios is crucial for constructing and monitoring a consistent climate investment strategy. Several frameworks have emerged in recent years to perform attribution analyses, and which aim to identify the drivers behind portfolio decarbonisation over time. This article provides a qualitative and quantitative comparative analysis of these frameworks, examining the key drivers identified and the methods used to isolate the effects of each driver. Based on this review, we formalise a generalisation approach to combine them, and recommend five models that are tailored to answer specific questions. These models should help investors to better understand the drivers behind portfolio emissions metrics changes and distinguish the exogenous drivers over which they have limited control from those where they can exert direct influence.

Key takeaways

- Since 2022, several attribution frameworks have been developed to help investors better understand the drivers influencing change in emissions metrics – absolute emissions, emissions intensity, and emissions footprint – associated with financial portfolios over time.
- The drivers identified across these frameworks can be classified into four main categories: data coverage, portfolio reallocation, economic and financial fluctuations, and company emissions. Two methods are commonly used to attribute change in emissions metrics to these drivers: the Laspeyres indicators and the logarithmic mean Divisia index.
- A quantitative example illustrates that these frameworks are complementary, and we show that it is possible to combine them through a three-step generalisation. This flexible approach enables investors to assess the contributions of various drivers such as strategic asset class allocation, divestment, sector allocation, stock selection, instrument price volatility, emissions scopes, company activity, inflation, to any change in portfolio emissions metrics.

Keywords

Greenhouse gas emissions, portfolio decarbonisation, attribution analysis

Introduction

Introduction

Asset owners can contribute to mitigating climate change through various means, including by reducing the emissions associated with their portfolios. Regulatory and voluntary frameworks have been established to support these efforts by defining metrics for measuring the indirect emissions associated with financial portfolios (PCAF, 2022), harmonising reporting standards related to the emissions of financial entities and instruments (SFDR, 2019), and offering emissions reduction target-setting protocols aligned with the Paris Agreement's goals¹.

Despite these developments, investors still face challenges in understanding and controlling the evolution of portfolio emissions over time. Since 2022, several attribution frameworks have been introduced to help investors better understand the drivers influencing the emissions metrics associated with financial portfolios (Bouchet, 2023; NZAOA, 2023; Nagy, Giese and Wang, 2023; Simmons et al., 2022). NZAOA (2023) identify several purposes of attribution analysis, with the overarching goal of enabling asset owners and managers to understand the emissions drivers in a portfolio and take informed action. Depending on the type of financial management, actions may involve divestment, portfolio reallocation, corporate engagement, or dialogue with asset managers to assess and challenge their decarbonisation performance. Attribution analysis can also enhance transparency for public reporting, as frameworks like the Science Based Targets initiative (SBTi) recommend financial institutions report and attribute changes in emissions, as well as progress on target indicators, using three levels of details². Undertaking attribution analysis is therefore increasingly recommended in frameworks for institutional investors, such as the second version of the Net Zero Investment Framework from the Institutional Investors Group on Climate Change (IIGCC, 2024a). This article compares the main existing attribution frameworks, highlighting their similarities, differences, and explores how they can be combined to offer more flexibility to investors seeking answers to questions specific to their portfolios.

The first section compares frameworks based on the type of portfolio analysed, the emissions metric used, the identified drivers, and the attribution method. Most frameworks focus on historical analysis of absolute emissions, emissions intensity, and the emissions footprint³ of equity portfolios. The identified drivers that explain change in a metric over time can be grouped into four main categories: data coverage, portfolio reallocation, economic and financial fluctuations, and company emissions. Differences between the frameworks primarily arise from portfolio reallocation drivers, with some models emphasising the impact of investment universe variations and others focusing on sector and intra-sector reallocations. Two methods are used to attribute change in emissions metrics between drivers. The first is based on Laspeyres (1871) price and quantity indicators, traditionally used to analyse price index change. The second is the logarithmic mean Divisia index (LMDI), derived from environmental economics (Ang, Zhang and Choi, 1998). While the Laspeyres method aligns with established portfolio performance decomposition techniques (Brinson and Fachler, 1985; Brinson, Hood, and Beebower, 1986), it introduces interaction terms that can be challenging to interpret and requires a hierarchical arrangement of drivers. The LMDI approach treats all drivers equally without interaction terms, though it is more complex to implement.

1 - European Union climate transition and Paris-aligned benchmarks delegated regulation, target setting protocol of the Net-Zero Asset Owner Alliance, net-zero investment framework of the Paris Aligned Investment Initiative.

2 - "Changes in actual underlying emissions and target indicators, changes due to re-allocation within portfolios, and changes due to technical elements, such as data quality improvements, reporting, and GHG quantification methodology changes, etc." (SBTi, 2023, p.65).

3 - Depending on the context, emissions footprint is also called emissions intensity per EVIC (enterprise value including cash). In the following, intensity refers to intensity per revenue, and emissions footprint refers to intensity per EVIC.

Introduction

In the second section, models inspired by these frameworks are applied to a simplified fictitious portfolio, analysing its absolute emissions, emissions intensity, and emissions footprint. The analysis shows that the frameworks offer complementary insights into the evolution of these metrics. Regarding the attribution method, the Laspeyres method seems preferable for models with fewer than three drivers, while the LMDI method is better suited for models with more drivers.

To enhance the flexibility of these models in addressing specific investor concerns, a three-step generalisation is formalised in the third section to combine previous drivers. The first step involves choosing relevant subsets of instruments (e.g., excluded instruments, instruments with missing emissions data) for which the effect on the metric must be isolated. The second step is to express the emissions metric (absolute emissions, intensity, or footprint) as a product of variables (representing drivers) at the instrument level. Finally, the third step involves selecting an attribution method and its parameters. This flexible approach is illustrated with five model variations designed to assess the contribution of strategic asset class allocation, divestment, sector allocation, stock selection, instrument price volatility, emissions scopes, company activity, inflation, to any change in portfolio emissions metrics.

Attribution analysis of changes in portfolio emissions metrics enables investors to better understand the drivers behind these changes and distinguish between exogenous drivers, over which they have limited control (e.g., instrument price volatility), and drivers where they can exert influence (e.g., divestment, sector allocation, stock selection). As a result, attribution analysis is a crucial tool for constructing and monitoring a climate investment strategy. The generalised model proposed in this article aims to make attribution analysis more flexible and easier to implement, adapting to the specific needs of investors.

1. Design Comparison of Existing Attribution Frameworks

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This section compares the design choices of the attribution frameworks developed by Simmons et al. (2022), Bouchet (2023), Nagy, Giese and Wang (2023), and NZAOA (2023). Attribution analysis can be applied to various types of portfolios and emissions metrics, with each framework identifying distinct drivers that explain changes in these metrics.

Two primary methods for attributing change in the metrics to each driver are commonly used.

1.1 Portfolios, Metrics, and Type of Analysis

The portfolio to be analysed is an important characteristic in the attribution analysis. First, the asset class present in the portfolio will guide the choice of emissions metrics, depending on whether the instruments are listed or not, whether they are debt or equity products, and whether they are related to companies, projects, real estate or countries. Existing frameworks have mainly been applied to equity portfolios, in particular benchmarks or indices (Exhibit 1).

Exhibit 1: Review of existing portfolios, metrics and types of analysis

Framework	Portfolio analysed	Metrics	Type of analysis
Simmons et al. (2022)	Equity benchmark (FTSE All-World Index)	Emissions intensity	Historical
Bouchet (2023)	Equity index (climate impact index)	Absolute emissions Emissions intensity	Cross-sectional Historical
Nagy, Giese and Wang (2023)	Equity benchmark (MSCI ACWI Investable Market Index) Exchange-traded fund (ETF) (US minimum-volatility ETF)	Absolute emissions Emissions intensity Emissions footprint	Historical
NZAOA (2023)	(listed) corporates bonds and equity portfolio	Absolute emissions Emissions intensity Emissions footprint	Historical

Three emissions metrics are analysed by existing attribution frameworks: absolute emissions, emissions intensity and emissions footprint. Rather than alternatives, these three metrics are regarded as complementary by climate frameworks (Bouchet, 2023). Whatever the metric, emissions correspond to direct emissions (Scope 1), indirect emissions linked to energy consumption (Scope 2), or indirect emissions linked to the value chain (Scope 3). The inclusion of Scope 3 emissions is the subject of recurrent debate, due to their high proportion compared to Scope 1 and 2 emissions and their methodological limitations (Ducoulombier, 2021, 2024). The third section demonstrates that attribution analysis can address this issue by disentangling the contributions of each emissions scope.

Most attribution frameworks have been developed to analyse a portfolio over a period. While this historical analysis is the most important for understanding a portfolio's contribution to emissions reductions targets, it may be useful to supplement it with a cross-sectional analysis to understand the differences between two portfolios at a given time. The EU climate transition and Paris-aligned benchmarks regulation requires for example that the 'Paris-aligned' benchmark "GHG [Greenhouse gas] intensity [...] shall be at least 50 % lower than the GHG intensity or absolute GHG emissions of the

1. Design Comparison of Existing Attribution Frameworks

*investable universe*⁴. Examples of cross-sectional analysis between a climate index and its reference universe are provided in Bouchet (2023).

1.2 Drivers that Explain Change in an Emissions Metric

The drivers identified within the existing frameworks can be grouped into four main categories: data coverage, portfolio reallocation, financial and economic fluctuations, and company emissions. They also differ depending on whether the metric being analysed is absolute emissions or intensity-based (emissions intensity or emissions footprint) (Exhibit 2). While the names of the categories may vary, the first aim is to distinguish *“the effects of drivers that investors have no influence on (passive actions), such as the effects of financial metrics or increased data quality on emissions, from drivers that investors control (active actions), such as stock selection”* (IIGCC, 2024b, p. 29).

- The first category of drivers is related to data coverage. Emissions of a company may first change due to variations in data coverage, especially if companies' emissions data are available in the most recent period but not in previous periods. As discussed in Section 3, the effects of changes in methodology, particularly on Scope 3, can also be included in this category.
- The second set of drivers relates to portfolio reallocation, which includes decisions to divest, buy new instruments, or any buy and sell decisions related to existing instruments. These reallocation decisions can be captured by two variables: the financial weight of an instrument in the portfolio and the share of a company held by the portfolio. However, change in weight may result from deliberate buy and sell decisions but can also be driven by financial fluctuations in instrument prices. In contrast, the share of a company held – particularly within a homogeneous asset class like equity – can only be influenced by buy and sell decisions. Therefore, accounting for price effects in weight variations is essential. Bouchet (2023) further differentiates between sector allocation and stock selection drivers. From a climate impact perspective, sector allocation can, to some extent, be seen as an artificial way to reduce emissions, simply by reducing exposure to high-emission sectors. For example, the IIGCC (2023) recommends that net-zero benchmarks prioritise real-world 'organic' decarbonisation over 'paper' decarbonisation and advocates incorporating a sectoral approach.
- The third category of drivers concerns economic and financial fluctuations. Variations in enterprise value, including cash (EVIC) – particularly the equity component – can impact the financial structure of companies (i.e., the proportion of equity versus debt) and, consequently, the emissions associated with the portfolio. Since these drivers are largely exogenous to the investor, isolating their effects is critical to focusing on emission reduction drivers directly related to investor decisions.
- The final category of drivers is related to company emissions. Emissions can change due to a change in emissions intensity and a change in revenue. However, revenue may be heavily influenced by inflation. In such cases, the intensity indicator may not accurately reflect production efficiency improvements, and it may be relevant to introduce an inflation driver.

4 - From the Commission delegated regulation (EU) 2020/1818.

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Exhibit 2: Drivers in existing attribution frameworks

a) Analysis of change in absolute emissions

Driver type	Driver	Bouchet (2023)	Nagy, Giese and Wang (2023)	NZAOA (2023)
Data coverage	Data coverage		X	X
Portfolio reallocation (buy/sell decisions)	New positions		X	X
	Deleted positions		X	X
	Financing share		X	
Portfolio reallocation (buy/sell decisions) and/or financial fluctuations	Sector weight	X		
	Instrument weight within sector	X		
	Financing value			X
	Portfolio AUM	X		
Financial and economic fluctuations	Financing structure		X	
	EVIC	X		X
	Revenue	X		
Financial and economic fluctuations and/or Company emissions	Emissions intensity	X		
Company emissions	Emissions		X	X

b) Analysis of change in emissions intensity or footprint

Driver type	Driver	Simmons et al. (2022)	Bouchet (2023)	Nagy et al. (2023)	NZAOA (2023)
Data coverage	Data coverage			X	X
Portfolio reallocation (buy/sell decisions)	New positions	X		X	X
	Deleted positions	X		X	X
Portfolio reallocation (buy/sell decisions) and/or financial fluctuations	Sector weight		X		
	Instrument weight within sector		X		
	Instrument weight within portfolio	X		X	X
Financial and economic fluctuations	Revenue	X		X	X
Financial and economic fluctuations and/or Company emissions	Emissions intensity		X		
Company emissions	Emissions	X		X	X

Notes: NZAOA (2023) uses the following terms: Changes in coverage (Data coverage), real world emissions reduction (Emissions), Investment portfolio reallocation, enterprise value or revenue of investee companies. Nagy et al. (2023) use the following terms: portfolio inflows (new positions) and outflows (deleted positions), ownership in each portfolio company (financing share), financing structure (equity/debt) for each company, companies' emissions. Bouchet (2023) uses the following terms: sector allocation (weight of a given sector in portfolio), intra-sectoral allocation (weight of a stock in the sector), emissions intensity of the firms (expressed as tonnes of CO₂e per million dollars of sales), sales and market capitalisation. Simmons et al. (2022) and Nagy, Giese and Wang (2023) use the following terms: weight, EVIC, companies' emissions.

1. Design Comparison of Existing Attribution Frameworks

1.3 Methods of Attribution

The two main methods are used for attributing a change in the emissions metric to each driver are the Laspeyres and the LMDI method. Let us consider M_p as an emission metric at portfolio level which can be expressed as the sum for J instruments of a product of N variables (drivers):

$$M_p = \sum_{j=1}^J M_j = \sum_{j=1}^J D_{1,j} \cdot D_{n,j} \dots D_{N,j} = \sum_{j=1}^J \prod_{n=1}^N D_{n,j}$$

where M_j represents the contribution of instrument j to the portfolio metric, and $D_{n,j}$ the drivers.

The goal of an attribution method is to express the change from M_p^{t0} to M_p^{t1} as an additive⁵ decomposition of effects E_{D_n} corresponding to each driver D_n .

$$M_p^{t1} - M_p^{t0} = \Delta M_p = E_{D_1} + E_{D_n} + \dots + E_{D_N}$$

Nagy, Giese and Wang (2023) and NZAOA (2023) rely on a method derived from the Laspeyres (1871) price and quantity indicators, which are commonly used to analyse changes in price indexes. This method is analogous to the framework used to decompose a portfolio's financial performance (Brinson and Fachler, 1985; Brinson, Hood, and Beebower, 1986). As noted by NZAOA (2023), "the calculation of emissions attribution is similar to the calculation of performance attribution. For both, one breaks down the overall change in a metric (emissions or performance) into its constituents, explaining allocation and selection effects. For a performance analysis, a market benchmark is usually used. For emissions attribution, it is the initial portfolio that takes the role of a benchmark in most cases" (p.4).

To illustrate this method, consider the case of two drivers:

$$M_p = \sum_{j=1}^J D_{1,j} \cdot D_{2,j}$$

$$\Delta M_p = \underbrace{\sum_{j=1}^J \Delta D_{1,j} \cdot D_{2,j,t0}}_{E_{D_1}} + \underbrace{\sum_{j=1}^J \Delta D_{2,j} \cdot D_{1,j,t0}}_{E_{D_2}} + \underbrace{\sum_{j=1}^J \Delta D_{1,j} \cdot \Delta D_{2,j}}_{I_{\Delta D_1, \Delta D_2}}$$

where $I_{\Delta D_1, \Delta D_2}$ is an interaction term between the two variations ΔD_1 and ΔD_2 .

When considering more than two drivers, the same formula can be applied recursively by decomposing the initial product into multiple layers, with each layer corresponding to the product of two variables. To simplify the notation, the analysis can focus on a single instrument, as we can then sum the effects for all the instruments in the portfolio.

The principle of layers is illustrated below for the case of $N=3$ with a generalisation provided in Appendix 5.1.

⁵ -While it is less common in the existing attribution frameworks, the attribution can also be multiplicative. In this case, the change in the emissions metric is expressed as follows: $\frac{M^{t1}}{M^{t0}} = E_{D_1} \cdot E_{D_2} \dots E_{D_n}$.

1. Design Comparison of Existing Attribution Frameworks

$$M_j = D_1 \cdot D_2 \cdot D_3 = \underbrace{D_1}_{1st\ layer} \cdot \underbrace{(D_2 \cdot D_3)}_{2nd\ layer}$$

The first layer is used to calculate E_{D_1} , and is associated with the interaction term I_{l_1} .

$$\Delta M_j = \underbrace{\Delta D_1 \cdot (D_2 \cdot D_3)_{t0}}_{E_{D_1}} + \underbrace{\Delta(D_2 \cdot D_3) \cdot D_{1,t0}}_{2nd\ layer} + \underbrace{\Delta(D_2 \cdot D_3) \cdot \Delta D_1}_{I_{l_1}}$$

The second layer can be decomposed as follows:

$$\Delta(D_2 \cdot D_3) \cdot D_{1,t0} = (\Delta D_2 \cdot D_{3,t0} + \Delta D_3 \cdot D_{2,t0} + \Delta D_2 \cdot \Delta D_3) \cdot D_{1,t0}$$

$$\Delta(D_2 \cdot D_3) \cdot D_{1,t0} = \underbrace{\Delta D_2 \cdot (D_3 \cdot D_1)_{t0}}_{E_{D_2}} + \underbrace{\Delta D_3 \cdot (D_2 \cdot D_1)_{t0}}_{E_{D_3}} + \underbrace{\Delta D_2 \cdot \Delta D_3 \cdot D_{1,t0}}_{I_{l_2}}$$

Note that while the effects associated with each driver are stable, the interaction terms depend on the order of the drivers and therefore on the layers.

One limitation of this method is the difficulty in interpreting the interaction terms ("*interaction terms are undesirable because the goal of performance attribution is to identify each factor's independent contribution*" (NZAOA, 2023, p.22). In their consensus approach, they recommend distributing the interaction terms equally among the changes in drivers to mitigate this issue⁶.

$$\Delta M_p = \underbrace{\sum_{j=1}^J \left(\Delta D_{1,j} \cdot D_{2,j,t0} + \frac{\Delta D_{1,j} \cdot \Delta D_{2,j}}{2} \right)}_{E_{D_1}} + \underbrace{\sum_{j=1}^J \left(\Delta D_{2,j} \cdot D_{1,j,t0} + \frac{\Delta D_{1,j} \cdot \Delta D_{2,j}}{2} \right)}_{E_{D_2}}$$

Another way to interpret this approach is by considering that, when calculating the effect E_{D_1} , the reference value for D_2 is not its value at the initial time $D_{2,t0}$, but its average value over the period $\bar{D}_2 = (D_{2,t0} + D_{2,t1})/2$. Factoring the previous equation:

$$\Delta M_p = \underbrace{\sum_{j=1}^J \left(\Delta D_{1,j} \cdot \left(D_{2,j,t0} + \frac{\Delta D_{2,j}}{2} \right) \right)}_{E_{D_1}} + \underbrace{\sum_{j=1}^J \left(\Delta D_{2,j} \cdot \left(D_{1,j,t0} + \frac{\Delta D_{1,j}}{2} \right) \right)}_{E_{D_2}} = \underbrace{\sum_{j=1}^J (\Delta D_{1,j} \cdot \bar{D}_2)}_{E_{D_1}} + \underbrace{\sum_{j=1}^J (\Delta D_{2,j} \cdot \bar{D}_1)}_{E_{D_2}}$$

On the other hand, Simmons et al. (2022) and Bouchet (2023) rely on the logarithmic mean Divisia index, a common method used environmental economics (Ang, Zhang and Choi, 1998). As developed in Ang (2015), the additional effects of the driver D_n is given by:

$$E_{D_n} = \sum_{j=1}^J L(M_j^{t1}, M_j^{t0}) \cdot \ln \left(\frac{D_{n,j,t1}}{D_{n,j,t0}} \right)$$

where $L(M_j^{t1}, M_j^{t0}) = M_j^{t1} - M_j^{t0} / \ln(M_j^{t1}) - \ln(M_j^{t0})$.

6 - The same approach is proposed by Nagy et al. (2023).

1. Design Comparison of Existing Attribution Frameworks

Both the Laspeyres and the LMDI methods have distinct advantages and limitations. The effects associated with a driver calculated using the Laspeyres method are easier to interpret, as they represent the variation in the metric caused by a change in the driver while holding all other drivers at their initial state. However, the Laspeyres method introduces interaction terms that can be challenging to interpret, and it lacks symmetry – analysing the difference between t_0 and t_1 versus t_1 and t_0 yields different results⁷. Additionally, as more drivers are considered, the number of interaction terms increases. These can be eliminated using the average method, but the results remain sensitive to the order in which the variables are decomposed. For example, decomposing $M_j = D_1 \cdot D_2 \cdot D_3$ will not yield the same results as decomposing $M_j = D_3 \cdot D_2 \cdot D_1$.

In contrast, the effects calculated using the LMDI method are more complex to interpret due to the involvement of logarithms, and handling zero values requires special attention (Appendix 5.2). However, the LMDI method eliminates interaction terms regardless of the number of drivers, is symmetrical, and is not sensitive to the order of the drivers.

As a result, the Laspeyres method (with or without interaction terms) is recommended for models involving only two drivers, while the LMDI method is preferable for models with more drivers.

7 - This asymmetry is generally not an issue in historical analyses, where the situation at t_0 can be considered the reference point. However, it becomes more problematic in cross-sectional analyses comparing two portfolios, as the lack of symmetry can lead to inconsistent results depending on the choice of the reference portfolio.

2. Numerical Comparison of Existing Attribution Frameworks

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In this section, the existing attribution frameworks are compared by analysing, for a fictitious portfolio, the variations in its emissions metrics.

2.1 Definition of a fictitious portfolio

Four distinct companies are considered over one period, from t_0 to t_1 . Two of these companies belong to a 'brown' sector (BS), representing carbon-intensive industries, and the other two to a 'green' sector (GS). Within each sector, one company is considered highly intensive (HI) and the other low intensive (LI) compared to the sector average. A portfolio of four equity instruments is built from these companies. Changes in company variables and portfolio reallocation that should be reflected in the attribution analysis are detailed in Exhibit 3 and Exhibit 4.

Exhibit 3: Changes in company variables

Company (i)	Sector	Unit	BS-HI $i \in S_{brown}$	BS-LI $i \in S_{brown}$	GS-HI $i \in S_{green}$	GS-LI $i \in S_{green}$
Emissions and economic activity	$E1_{i,t_0}$	(tCO ₂ e)	75,000,000	25,000,000	15,000,000	5,000,000
	$E1_{i,t_1}$	(tCO ₂ e)	-	50,000,000 (a)	-	-
	$E2_{i,t_0}$	(tCO ₂ e)	25,000,000	12,500,000	5,000,000	2,500,000
	$E2_{i,t_1}$	(tCO ₂ e)	12,500,000 (b)	6,250,000 (b)	2,500,000 (b)	1,250,000 (b)
	P_{i,t_0}	t	100	100	100	100
	P_{i,t_1}	t	-	-	-	-
	R_{i,t_0}	(MUSD)	100,000	100,000	100,000	100,000
	R_{i,t_1}	(MUSD)	-	150,000 (c)	-	-
Financing structure	QE_{i,t_0}		100,000,000	100,000,000	100,000,000	100,000,000
	QE_{i,t_1}		-	-	-	-
	PE_{i,t_0}	(USD)	1,000	1,000	1,000	1,000
	PE_{i,t_1}	(USD)	1,200 (d)	1,300 (d)	1,300 (d)	1,500 (d)
	QD_{i,t_0}	-	50,000,000	50,000,000	50,000,000	50,000,000
	QD_{i,t_1}	-	-	-	-	100,000,000
	PD_{i,t_0}		1,000	1,000	1,000	1,000
	PD_{i,t_1}		-	-	-	-
	$EVIC_{i,t_0}$	(MUSD)	150,000	150,000	150,000	150,000
	$EVIC_{i,t_1}$	(MUSD)	170,000	180,000	180,000	250,000 (e)

Notation: $E1$ are the direct emissions (Scope 1) of a company, $E2$ are its indirect emissions related to electricity consumption (Scope 2), and E its total emissions. $Prod$ represent the company's physical production (expressed in tonnes), R its revenue, QE its quantity of equity instruments, PE the price per equity instrument, QD the quantity of debt instruments, PD the price per debt instrument, and $EVIC$ the enterprise value including cash.

Scenario: Due to an increase in activity, BS-LI's direct emissions increase by 100% (a) while its revenue increases only by 50% (c). Indirect emissions linked to electricity consumption by all companies decrease by 50% (b). Regarding financial variables, the price per equity instrument of all companies increases between 20% and 50% (d) – resulting in increases in $EVIC$ increasing. GS-LI's $EVIC$ also increases due to a debt issuance (e).

2. Numerical Comparison of Existing Attribution Frameworks

Exhibit 4: Changes in portfolio reallocation

Instrument (j)	Unit	BS-HI	BS-LI	GS-HI	GS-LI
Type of instrument		Equity	Equity	Equity	Equity
$N_{j,t0}$		25,000	25,000	25,000	25,000
$N_{j,t1}$		0.0	41,666	20,833	41,666
$PI_{j,t0}$	USD	1,000	1,000	1,000	1,000
$PI_{j,t1}$	USD	-	-	2,000	-
$W_{j,t0}$	%	25.0%	25.0%	25.0%	25.0%
$W_{j,t1}$	%	0.0% (a)	33.3%	33.3%	33.3%
$W_{s(i(j)),t0}$	%	50.0%	50.0%	50.0%	50.0%
$W_{s(i(j)),t1}$	%	33.3%	33.3%	66.7%	66.7%
$W_{is(i(j)),t0}$	%	50.0%	50.0%	50.0%	50.0%
$W_{is(i(j)),t1}$	%	0.0%	100.0%	-	-

Notation: N represents the quantity of instruments in the portfolio, PI the price per instrument, w its financial weight in the portfolio, w_s the weight of the sector to which the company issuing the instrument belongs, and w_{is} the financial weight of the instrument within this sector $w_{is} = w/w_s$.

Scenario: The manager decides to divest the most intensive company (a) and reallocates equally between the three remaining instruments.

2.2 Analysis of Change in Absolute Emissions

The absolute emissions associated with the portfolio, E_p , are defined as follows:

$$E_p = \sum_j E_{j,t}^p = \sum_j \left(\frac{N_j \cdot PI_j}{\underbrace{EVIC_{i(j)}}_{EVIC \text{ share}}} \right) \times E_{i(j)}$$

where E_j^p represents the absolute emissions⁸ associated with instrument j , N_j the quantity of instruments held in the portfolio, PI_j the price per instrument, $EVIC_{i(j)}$ the enterprise value of the company that issued the instrument, and $E_{i(j)}$ its emissions.

Given changes in company variables and portfolio reallocation, the absolute emissions associated with the portfolio decreased from 27,500 tonnes of CO₂ equivalent (tCO₂e) to 19,200 tCO₂e over the period. While this reduction in absolute emissions may initially appear positive from a climate impact perspective, it could be driven by exogenous drivers (e.g., financial volatility of instrument), or by drivers with limited real-world impact (e.g., sector reallocation).

Attribution analysis frameworks offer a valuable tool to measure the contributions of each type of driver. In the following subsections, the models are presented in a simplified form by decomposing the emissions metric at a given point in time, with the formulas for calculating the effects associated with each driver for each framework outlined in Section 3.

8 - Only scope 1 and scope 2 emissions are considered, but the same reasoning applies to scope 3 emissions.

2. Numerical Comparison of Existing Attribution Frameworks

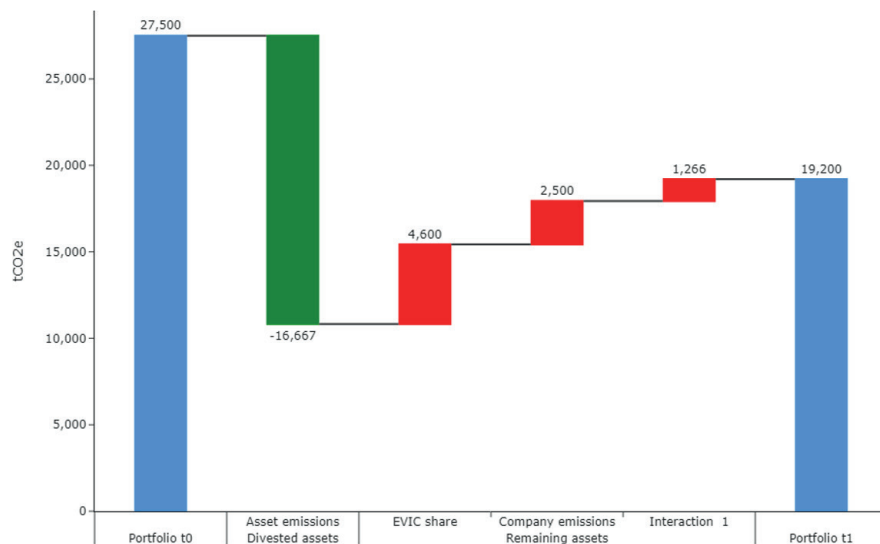
Understanding the Contribution of Divestment, Reallocation and Company Emissions

The first model is derived from the consensus approach recommended by NZAOA (2023). It decomposes the change in emissions into the following drivers: divested instruments, change in EVIC share, and change in company emissions.

$$E_p = \sum_{j \in \text{Divested instruments}} E_j^p + \sum_{j \in \text{Remaining instruments}} \left(\frac{N_j \cdot PI_j}{EVIC_{i(j)}} \right) \cdot E_{i(j)}$$

The Laspeyres method with interaction terms is used to compute the effects associated with these drivers. The results highlight the major effect of divesting the most intensive company (BS-HI) in reducing the portfolio's absolute emissions. For the remaining instruments, absolute emissions of the portfolio increase as a result of a change in EVIC share, but also as a result of company emissions increasing (Exhibit 5).

Exhibit 5: Attribution in change in absolute emissions by divestment, exposure, and company emissions



Notes: Model derived from NZAOA (2023). Analysis of a fictitious portfolio using the Laspeyres method with an interaction term.

Decomposing the EVIC Share Effect

The second model, derived from Nagy al. (2023), decomposes the 'EVIC share' effect from the previous model into a 'financing share' driver, a change in the proportion of a company held by the portfolio within a type of instrument (equity or debt), and a 'financial structure' driver, and a change in the company's financing structure (equity or debt as a proportion of total financing).

$$E_p = \sum_{j \in \text{Divested instruments}} E_j^p + \sum_{j \in \text{Remaining instruments}} \left(\frac{N_j}{QE_{i(j)}} \right) \cdot \left(\frac{QE_{i(j)} \cdot PE_{i(j)}}{EVIC_{i(j)}} \right) \cdot E_{i(j)}$$

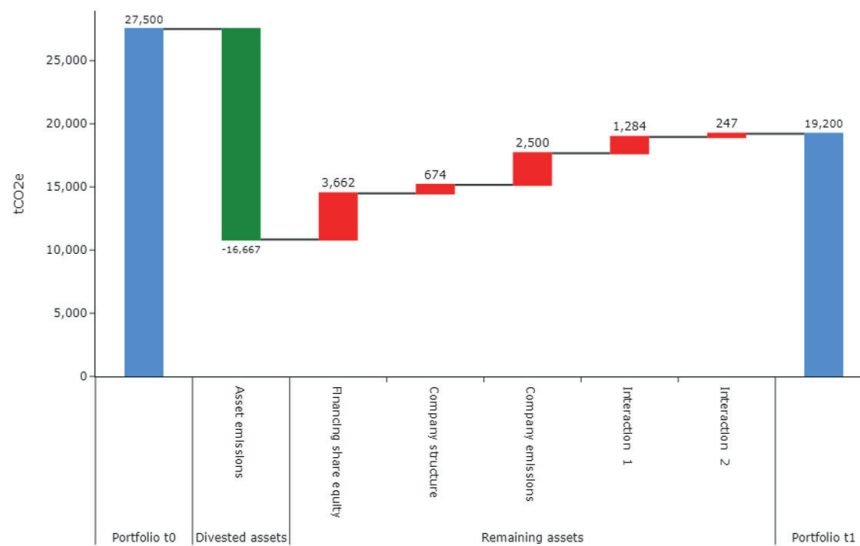
where $QE_{i(j)}$ represents the total quantity of the same instrument type as j issued by the company (equity instruments in our case), and $PE_{i(j)}$ represents the price per instrument.

2. Numerical Comparison of Existing Attribution Frameworks

While most of the effect associated with the ‘EVIC share’ driver comes from the ‘financing share’ driver, the ‘financial structure’ contributes to increase the absolute emissions. This effect can be explained as follows:

For GS-LI, the debt issuance between t0 and t1 tends to dilute the responsibility of equity owners, which tends to reduce the emissions associated with the portfolio. Conversely, for GS-HI, BS-LI, and BS-HI, the increase in the price per equity instrument increases the proportion of equity in the company’s financing, which tends to increase the emissions associated with the portfolio. Given that the initial emissions of these three companies are higher than those of GS-LI, the ‘financial structure’ effect at the portfolio level – which results from the sum of the effects among instruments – is an increase in absolute emissions (Exhibit 6).

Exhibit 6: Attribution in change in absolute emissions by divestment, financing share, financial structure, and company emissions



Notes: Model derived from Nagy, Giese and Wang (2023). Analysis of a fictitious portfolio using the Laspeyres method with an interaction term.

Sector Allocation and Stock Selection

Finally, the model proposed by Bouchet (2023) considers different drivers related to portfolio investment reallocation and to company emissions. Regarding portfolio reallocation, it decomposes the effects associated with sector reallocation and the intra-sector reallocation (stock selection) since sector reallocation might be considered as an artificial way to reduce portfolio emissions. Regarding company emissions, it decomposes the effect of intensity (is the company more efficient?) from the effect of size (does the company sell more products and services?).

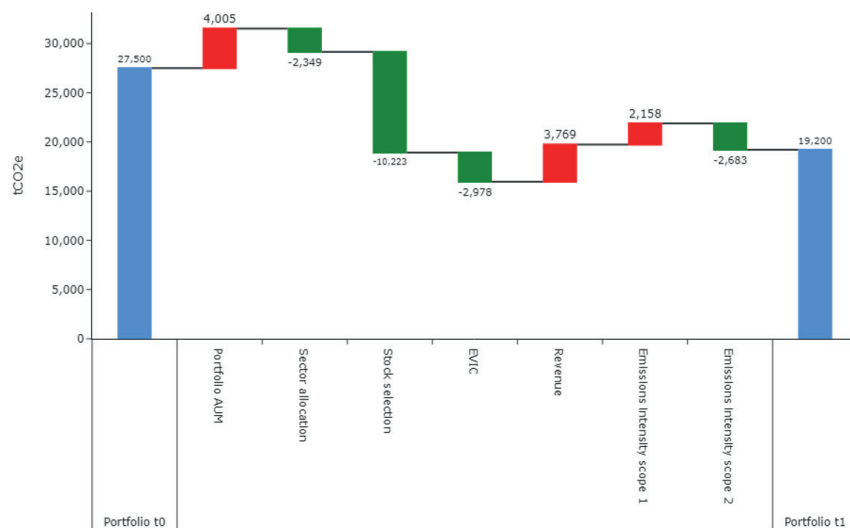
$$E_p = \sum_j \underbrace{V_p}_{\text{Portfolio value}} \cdot \underbrace{w_{s(i(j))}}_{\text{Sector allocation}} \cdot \underbrace{w_{is(i(j))}}_{\text{Stock selection}} \cdot \frac{1}{EVIC_{i(j)}} \cdot EI_{i(j)} \cdot R_{i(j)}$$

V_p represents the market value of the portfolio, $w_{s(i(j))}$ the weight of the sector to which the company issuing the instrument belongs, w_{is} the financial weight of the instrument within this sector ($w_{is(i(j))} = w_i / w_{s(i(j))}$), $EI_{i(j)}$ the emissions intensity of the company, and $R_{i(j)}$ its revenue.

2. Numerical Comparison of Existing Attribution Frameworks

In this example, both sector allocation and stock selection explain a large part of the reduction in portfolio absolute emissions. The results also show that the change in company emissions is explained by an increase in revenue (BS-LI), which is amplified by an increase in Scope 1 emissions intensity (due to BS-LI, which increases its revenue by 50% but its Scope 1 emissions by 100%), while Scope 2 intensity decreases (for all companies) (Exhibit 7).

Exhibit 7: Attribution in change in absolute emissions by sector allocation, stock selection, economic and financial fluctuations, and company intensity



Notes: Model derived from Bouchet (2023). Analysis of a fictitious portfolio using the LMDI method.

These three models explain the same change in portfolio absolute emissions by highlighting different drivers and are therefore complementary. In the first two models, the effect of divestment is the subject of a specific driver, while in the third model, divestment contributes to both the sector allocation and the stock selection effects. The third model provides a better understanding of the effects of activity size (change in revenue) at company level, and above all of scope effects.

2.3 Analysis of Change in Emissions Intensity

In this subsection, the frameworks are compared by analysing the change in emissions intensity of the portfolio, defined as follows:

$$EI_p = \sum_j w_j \cdot \underbrace{EI_{i(j)}}_{EI_j^p}$$

where EI_j^p represents the instrument contribution to the portfolio emissions intensity.

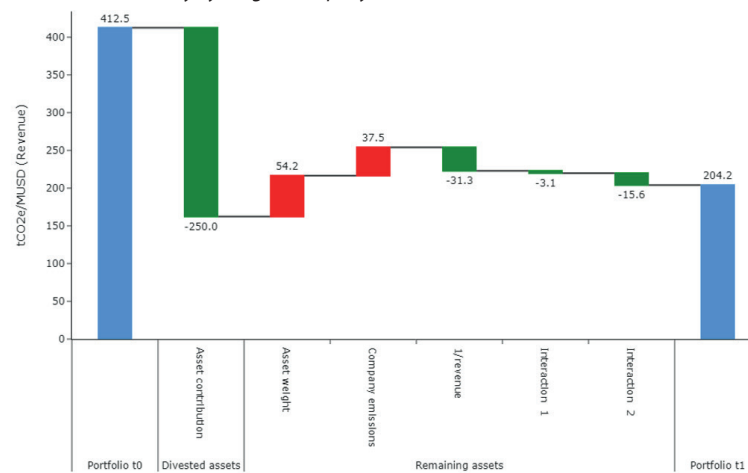
Given changes in company variables and portfolio reallocation, the emissions intensity of the portfolio also decreases over the period, from 412.5 tCO₂e/MUSD to 204.2 tCO₂e/MUSD. The fourth model, derived from Nagy, Giese and Wang (2023), highlights the effect of divestment, reallocation (instrument weight), company emissions, and revenue on this change (Laspeyres method).

2. Numerical Comparison of Existing Attribution Frameworks

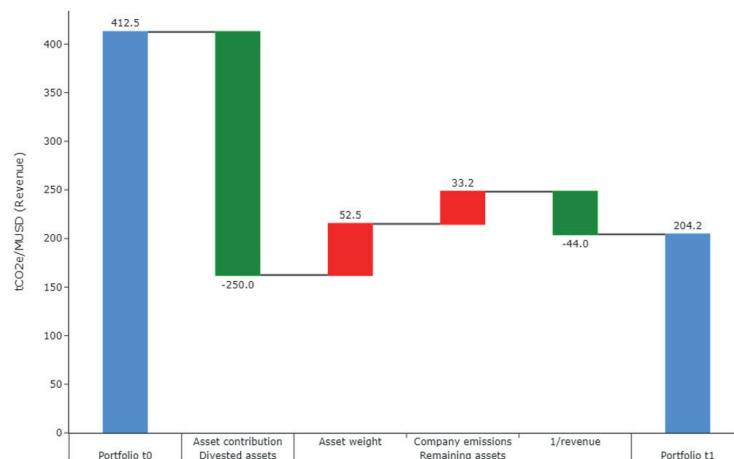
$$EI_p = \sum_{j \in \mathcal{P}_{\text{Divested assets}}} EI_j^p + \sum_{j \in \mathcal{P}_{\text{Remaining assets}}} w_j \cdot E_{i(j)} \cdot \frac{1}{R_{i(j)}}$$

The effects of divestment and reallocation are similar to those observed for absolute emissions. The breakdown between emissions and revenue drivers shows that the effect of the increase in absolute emissions is largely offset overall by an increase in revenue. Using the same drivers but the LMDI attribution method, a model derived from by Simmons et al. (2022) provides similar results. It should be noted, however, that the use of one method or the other slightly changes the resulting effect on the emissions intensity⁹. Using the Laspeyres method, the increase in emissions is not completely offset by the increase in revenue due to the effect associated with the interaction term (Exhibit 8a), while it is completely offset using the LMDI method (Exhibit 8b). Finally, a fifth model, derived from Bouchet (2023), shows similar results to the analysis of absolute emissions for sector allocation and stock selection drivers.

Exhibit 8: Attribution in change in emissions intensity by weight, company emissions, and revenue
a) With interaction terms



b) Without interaction terms



Notes: Model (a) is derived from Nagy, Giese and Wang (2023); model (b) is derived from Simmons et al. (2022). Analysis of a fictitious portfolio using the Laspeyres (a) and the LMDI (b) methods.

9 - A variation of this model proposed by Nagy et al. (2023) consists, for the 'instrument weight' driver, of subtracting the initial portfolio emissions intensity from each company emissions intensity. This can make it easier to interpret the effects associated with each driver (see Appendix 5.3).

2. Numerical Comparison of Existing Attribution Frameworks

2.4 Analysis of Change in Emissions Footprint

The third and last emissions metric for which the frameworks are compared is the emissions footprint of the portfolio, defined as follows:

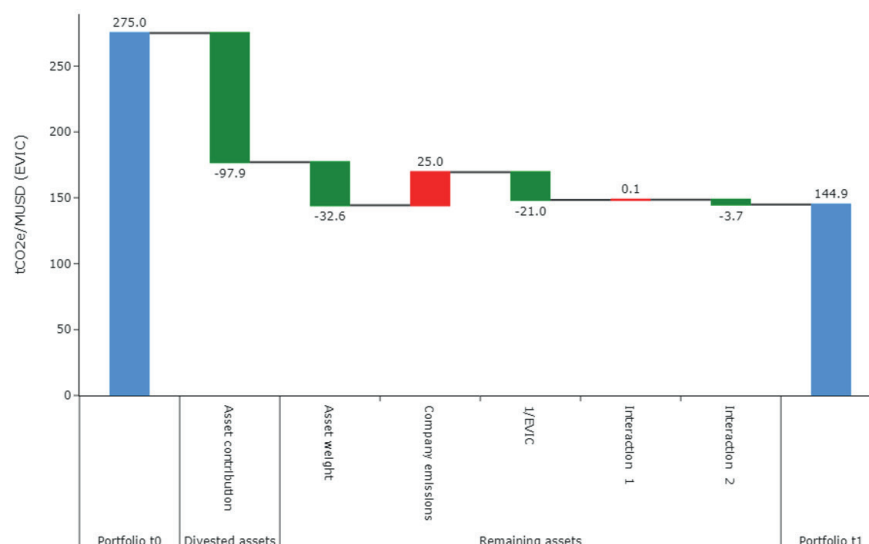
$$EF_p = \sum_j w_j \cdot EF_{i(j)}$$

where $EF_{i(j)}$ is the emissions footprint of the company that issued the instrument $EF_{i(j)} = E_{i(j)} / EVIC_{i(j)}$.

In the example, the emissions footprint of the portfolio decreases from 275.0 tCO₂e/MUSD to 144.9 tCO₂e/MUSD. Given that footprint is an intensity metric with a different denominator, EVIC instead of revenue, the decomposition structure is similar to the one presented in the previous subsection, and the results in terms of driver contribution are similar (Exhibit 9a).

A common practice is to adjust the emissions footprint of the portfolio for EVIC inflation (e.g., Simmons et al., 2022; Nagy, Giese and Wang, 2023). The attribution analysis carried out with this adjustment¹⁰ gives different results for the EVIC driver (as well as for the interaction terms). However, the effects associated with the drivers linked to divestment, reallocation and company emissions – which are those on which the portfolio manager has the most impact – remain identical (Exhibit 9). In the end, introducing an inflation adjustment factor on the portfolio emissions footprint or decomposing this footprint using a model that includes an EVIC driver are two ways of taking financial instrument price inflation into account, but combining them does not add value.

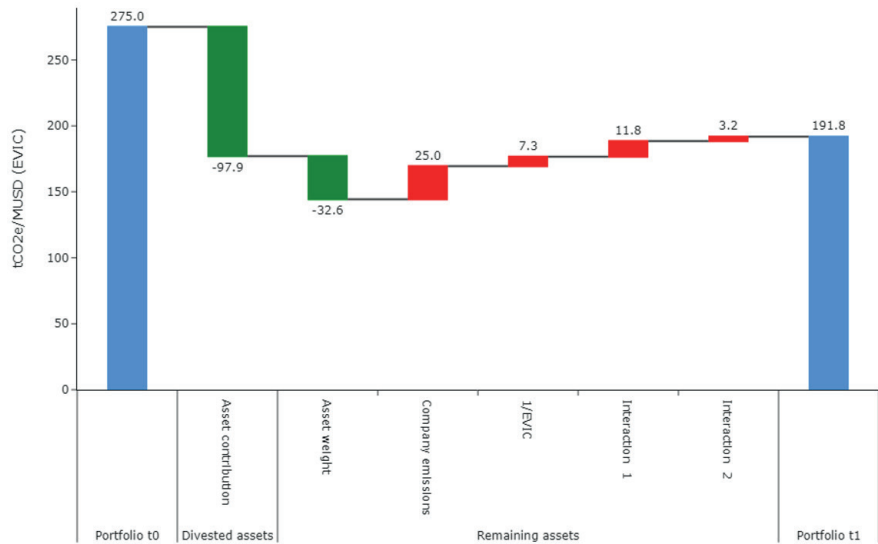
Exhibit 9: Impact of EVIC inflation adjustment on attribution in change in emissions footprint
a) No adjustment for EVIC inflation



10 - Detailed calculations are provided in the Appendix 5.5.

2. Numerical Comparison of Existing Attribution Frameworks

b) Adjustment for EVIC inflation



Notes: Model derived from Nagy, Giese and Wang (2023). Analysis of a fictitious portfolio using the Laspeyres (a) method with (a) and without (b) EVIC inflation adjustment.



3. Combining Drivers from Existing Frameworks

3. Combining Drivers from Existing Frameworks

Existing attribution frameworks provide complementary insights into change in a portfolio's emissions metrics through different drivers. However, it can be useful to combine their drivers to answer specific questions. A generalised approach to these frameworks is proposed in this section to combine the drivers discussed above in such a way as to adapt to one or other attribution method. Based on this approach, five models are developed for analysing a portfolio from the point of view of its extra-financial impact on emissions.

3.1 A Generalised Approach of Existing Frameworks

Let $\mathcal{P}$ be the set of all instruments in portfolio. The first step is to define disjoint subsets $\mathcal{P}_k$ of $\mathcal{P}$ that represent groups of instruments for which we want to isolate the contribution in the form of a driver (e.g. instruments that have been divested, instruments belonging to certain sectors etc.).

$$\mathcal{P} = \bigcup_{k=1}^K \mathcal{P}_k$$

with $\mathcal{P}_k \cup \mathcal{P}_l = \emptyset$ for all $k \neq l$, and K is the number of subsets.

The second step is to define, within each subset, a set of N_k drivers whose product is equal to the instrument contribution to the emissions metric¹¹ $M_{p,t}$

$$M_{p,t} = \sum_{k=1}^K f_k \left(\sum_{j \in \mathcal{P}_k} D1_j \cdot Dn_j \cdot \dots \cdot DN_{k_j} \right)$$

Note that these factors can be different depending on the subset. For example, in the case of absolute emissions, we might be only interested by the absolute emissions associated with an instrument for the subset 'divested assets' but by more drivers for the other instruments.

$$M_{p,t} = \sum_{j \in \mathcal{P}_{Divested\ instruments}} M_j^p + \sum_{j \in \mathcal{P}_{Remaining\ instruments}} \underbrace{D1_j \cdot D2_j \cdot \dots \cdot DN_{k_j}}_{E_j^p}$$

The third and last step is to choose an attribution method, to determine the effect of any driver D_n , between the Laspeyres method with interaction terms, the Laspeyres method without interaction terms, and the LMDI method (Exhibit 10).

Exhibit 10: Effect calculation for three attribution methods

Method	Formula for E_{D_n}
Laspeyres with interaction terms*	$E_{D_n} = \Delta D_n \cdot \prod_{k \neq n} D_{k,t0}$
Laspeyres without interaction terms**	$E_{D_n} = \Delta D_n \cdot \prod_{k=n+1}^N D_k \cdot \prod_{k=1}^{n-1} \overline{D_k}$
Logarithm mean Divisia index (LMDI)	$E_{D_n} = \sum_{j=1}^J \left[\left(\frac{M_j^{t1} - M_j^{t0}}{\ln(M_j^{t1}) - \ln(M_j^{t0})} \right) \cdot \ln \left(\frac{D_{n,j,t1}}{D_{n,j,t0}} \right) \right]$

Notes: *The interaction term associated with layer n is given in Appendix 5.1. ** For $N - 2 \leq n \leq N$, $E_{D_n} = \Delta D_n \cdot \prod_{k \neq n} \overline{D_k}$, see Appendix 5.1 for more details. As discussed in the previous section, whatever the method, for D_n corresponding to the financial weight driver, it is possible to subtract the initial portfolio emissions metric (intensity or footprint).

3. Combining Drivers from Existing Frameworks

3.2 Specific Models for Specific Questions

Based on this generalisation approach, five models are developed to answer different questions related to three of the four main categories of drivers presented in Section 1. Given the specific nature of data coverage issues, and in order not to overload the illustrations, questions relating to changes in data coverage or methodological changes are discussed in Appendix 5.5.

As these five models generally require more than three drivers, the attribution method used in this subsection (third step of the approach) is systematically the LMDI method, but the other two methods can also be implemented on the same drivers. To illustrate the results, the same companies introduced in the previous section are considered. However, the previous portfolio now holds debt instruments in order to cover multi-asset portfolios (Exhibit 11). Absolute emissions of this new portfolio decrease from 19,677 tCO₂e to 14,945 tCO₂e over the period, while its emissions intensity decreases from 295.0 tCO₂e/MUSD to 181.2 tCO₂e/MUSD.

Exhibit 11: Changes in a multi-asset portfolio

Instrument	Unit	BS-HI	BS-LI	GS-HI	GS-LI
Type of instrument		Equity	Equity	Debt	Debt
$N_{j,0}$		10,000	30,000	30,000	30,000
$N_{j,1}$		0.0	19,384	63,000	25,200
$Pl_{j,t0}$	USD	1,000	1,000	1,000	1,000
$Pl_{j,t1}$	USD	1,200	1,300	-	1,500
$W_{j,0}$	%	10.0%	30.0%	30.0%	30.0%
$W_{j,1}$	%	0.0%	20.0%	50.0%	30.0%
$W_{s(i(j)),t0}$	%	40.0%	40.0%	60.0%	60.0%
$W_{s(i(j)),t1}$	%	20.0%	20.0%	80.0%	80.0%
$W_{is(i(j)),t0}$	%	25.0%	75.0%	50.0%	50.0%
$W_{is(i(j)),t1}$	%	0.0%	100.0%	62.5%	37.5%

Notation: N represents the quantity of instrument in the portfolio, Pl the price per instrument, w its financial weight in the portfolio, w_s the weight of the sector to which the company issuing the instrument belongs, and w_{is} the financial weight of the instrument within this sector $w_{is} = w/w_s$.

Scenario: The portfolio manager has decided to divest completely from BS-HI, but also to reduce exposure to BS-LI and to reallocate his asset under management to the debt instruments of GS-HI.

What is the Contribution of Each Asset Class and Each Climate-Sensitive Sector?

To understand the extent to which the change in absolute emissions is explained by different asset classes (equity vs debt) and different sectors¹² (brown vs green), an initial model can be built using solely the first step of the generalised approach, i.e. defining disjoint subsets of the portfolio.

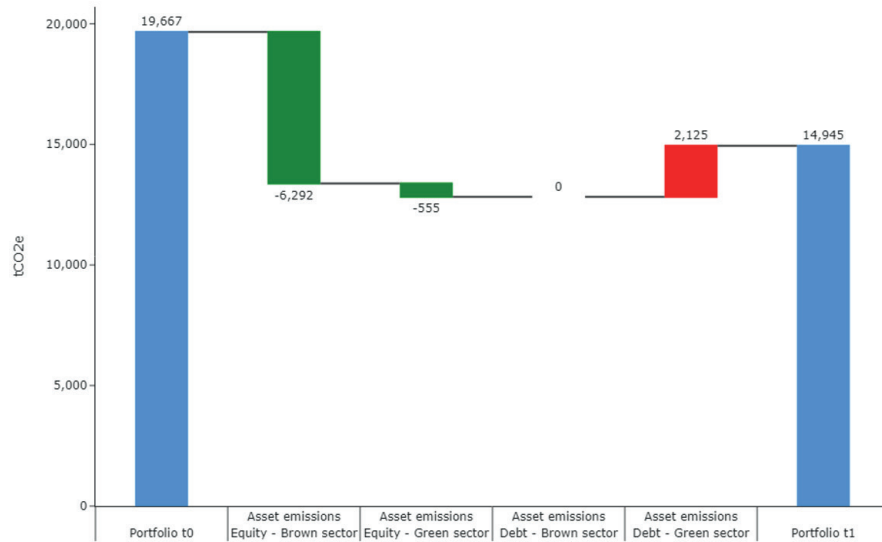
$$E_p = \sum_{j \in \mathcal{P}_{\text{Equity \& Brown}}} E_j^p + \sum_{j \in \mathcal{P}_{\text{Equity \& Green}}} E_j^p + \sum_{j \in \mathcal{P}_{\text{Debt \& Brown}}} E_j^p + \sum_{j \in \mathcal{P}_{\text{Debt \& Green}}} E_j^p$$

This initial analysis shows that most of the reduction comes from equity instruments in the brown sector (the sector to which the divested company belonged). On the other hand, the reallocation on debt instruments contributes to increasing the emissions (Exhibit 12).

12 - We use a simplified binary classification here, but it is possible to use classifications specially developed for the climate such as the high and low impact sectors put forward in European Regulation 2019/2089, the Climate Policy Relevant Sectors (Battiston et al., 2017), or sector partitions from net-zero investment frameworks, notably the UN-convened Net-Zero Asset Owner Alliance Target Setting Protocol.

3. Combining Drivers from Existing Frameworks

Exhibit 12: Attribution of change in absolute emissions by asset class and sector



Notes: Analysis of a fictitious portfolio using the LMDI method.

What is the Contribution of Divestment and Reallocation in this Reduction?

To further investigate the source of the observed reduction, it is essential to determine whether it is driven by divestment decisions, reallocations within the brown sector, or reductions in company emissions. A second model is employed to assess the impact of divestments, while also analysing, for the remaining instruments, the effects of the purchase or sale of instruments (buy/sell), financial fluctuations (instrument price volatility and company financial structure), and company emissions.

$$E_p = \sum_{j \in \mathcal{P}_{\text{Divested instruments}}} E_j^p + \sum_{j \in \mathcal{P}_{\text{Remaining instruments buy/sell}}} N_j \cdot \underbrace{PI_j \cdot \frac{1}{EVIC_{i(j)}}}_{\text{Financial fluctuations}} \cdot E_{i(j)}$$

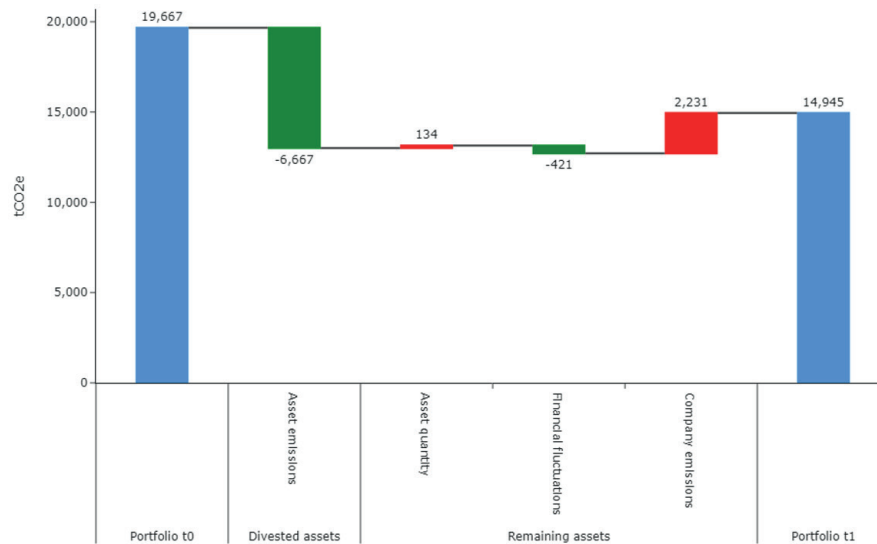
In the example, divestment accounts for a substantial proportion of the reduction in absolute emissions, while reallocations of the remaining securities and financial fluctuations have minimal impact. In contrast, company emissions increase overall during the period (Exhibit 13). From an extra-financial impact perspective, the apparent reduction in the portfolio's absolute emissions raises several concerns, as companies' organic emissions have generally risen. Given that the portfolio-level reduction is largely attributable to divestment, it is crucial to ensure that these divestment decisions are justified¹³. If the analyst has an exclusion list that is considered legitimate, e.g. as part of an analysis of the decarbonisation of an asset-owner that has strengthened its exclusion policy in the meantime, it is recommended that the effect of legitimate divestments be decomposed from other divestments as follows:

$$\sum_{j \in \mathcal{P}_{\text{Divested instruments}}} E_j^p = \sum_{j \in \mathcal{P}_{\text{Divested instruments in list}}} E_j^p + \sum_{j \in \mathcal{P}_{\text{Divested instruments not in list}}} E_j^p$$

13 - Either because the company is involved in controversial activities (e.g. exclusion criteria defined in Article 12 of the Delegated Regulation 2020/1818 regarding the European Union (EU) Climate Transition Benchmarks and EU Paris-aligned Benchmarks), or because an engagement campaign has not been successful.

3. Combining Drivers from Existing Frameworks

Exhibit 13: Attribution of change in absolute emissions by divestment, reallocation, financial fluctuations, and company emissions



Notes: Analysis of a fictitious portfolio using the LMDI method.

If the absolute emissions of companies have increased overall, this may be attributed to an increase in their emissions intensity or to an increase in their activity, such as increased market share. Therefore, it is essential to analyse the emissions intensity of the portfolio as well. As presented in the previous section, a change in intensity could result from shifts in the weight of instruments within the portfolio or from variations in company emissions intensity. However, instrument weights can fluctuate due to two drivers: buy/sell decisions, or instrument price changes. Similar to absolute emissions, the following model distinguishes between these effects on emissions intensity.

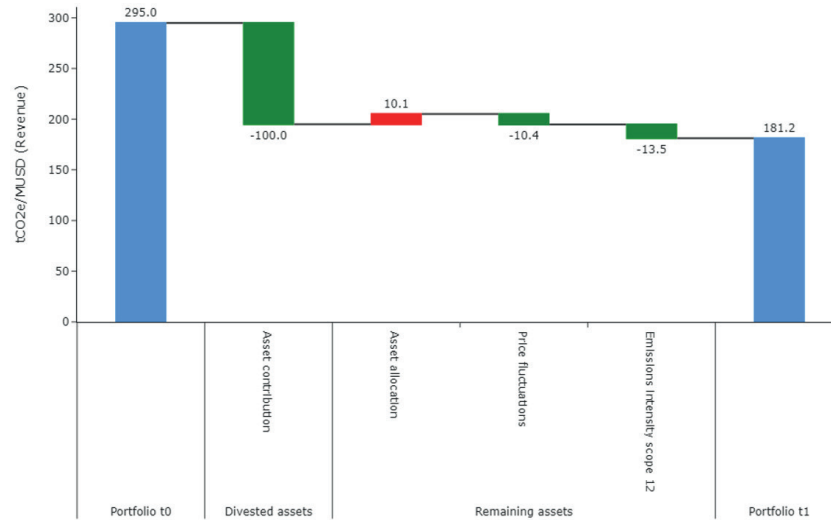
$$EI_p = \sum_{j \in \mathcal{P}_{\text{Divested instruments}}} EI_j^p + \sum_{j \in \mathcal{P}_{\text{Remaining instruments buy/sell}}} \underbrace{N_j}_{\text{Price fluctuations}} \cdot \underbrace{PI_j \cdot \frac{1}{V_p}}_{\text{Price fluctuations}} \cdot EI_{i(j)}$$

The results are consistent with the analysis of absolute emissions, as the effect of divestment – isolated in this case but potentially part of the quantity effect – is again observed. This is followed by a slight upward impact from buy and sell decisions, while price fluctuations contribute to reducing intensity. In contrast to absolute emissions, however, emissions intensity is declining. This can be attributed to the constant intensity of BS-LI, while the intensities of GS-HI and GS-LI are decreasing¹⁴ (Exhibit 14).

14 - The fact that BS-LI's activity is increasing tends to increase its absolute emissions.

3. Combining Drivers from Existing Frameworks

Exhibit 14: Attribution of change in intensity per revenue by divestment, allocation, price fluctuations, and company intensity



Notes: Analysis of a fictitious portfolio using the LMDI method.

What is the Contribution of Sector Allocation and Stock Selection?

The initial model of absolute emissions provided an overview of each sector's contribution but did not clarify whether the observed reductions were due to a decrease in sector exposure or reallocations within these sectors. This fourth model seeks to differentiate the impact of sector allocation from intra-sector allocation (i.e., stock selection). To maintain the isolation of the divestment effect, the analysis is restricted to the remaining instruments. A driver representing the change in weight of the remaining instruments (relative to the weight of the divested instruments) is introduced, allowing the model to isolate the effects of sector allocation and stock selection exclusively for the remaining stocks¹⁵.

$$EI_p = \sum_{j \in \mathcal{P}_{\text{Divested instruments}}} EI_j^p + \sum_{j \in \mathcal{P}_{\text{Remaining instruments (RI)}}} w_{RI} \cdot w_{s(i(j)),RI} \cdot w_{is(i(j)),RI} \cdot EI_{i(j)}$$

Even after isolating the effect of divestment, the reduction in intensity is primarily driven by sector allocation (shifting from brown to green sector). Moreover, stock selection within sectors contributes to an increase in intensity, as the weight of GS-HI within the green sector has increased relative to GS-LI (Exhibit 15a). In a context of significant price fluctuations, it is also possible to adjust these sector allocation and stock selection drivers to disentangle the effect of quantity and price changes on these weights. In the example, this adjustment reinforces the effects of sector allocation and stock selection (Exhibit 15b).

$$EI_p = \sum_{j \in \mathcal{P}_{\text{Div. instr.}}} EI_j^p + \sum_{j \in \mathcal{P}_{\text{Rem. instr. (RI)}}} w_{RI} \cdot aw_{s(i(j)),RI} \cdot aw_{is(i(j)),RI} \cdot \left(\frac{w_{s(i(j)),RI}}{aw_{s(i(j)),RI}} \cdot \frac{w_{is(i(j)),RI}}{aw_{is(i(j)),RI}} \right) \cdot EI_{i(j)}$$

where

$$aw_{j,t} = \frac{N_{j,t} \cdot P_{j,t0}}{\sum_j N_{j,t} \cdot P_{j,t0}}$$

and $aw_{j,t}$ is defined as follows (representing the weight at $t1$ without price fluctuation).

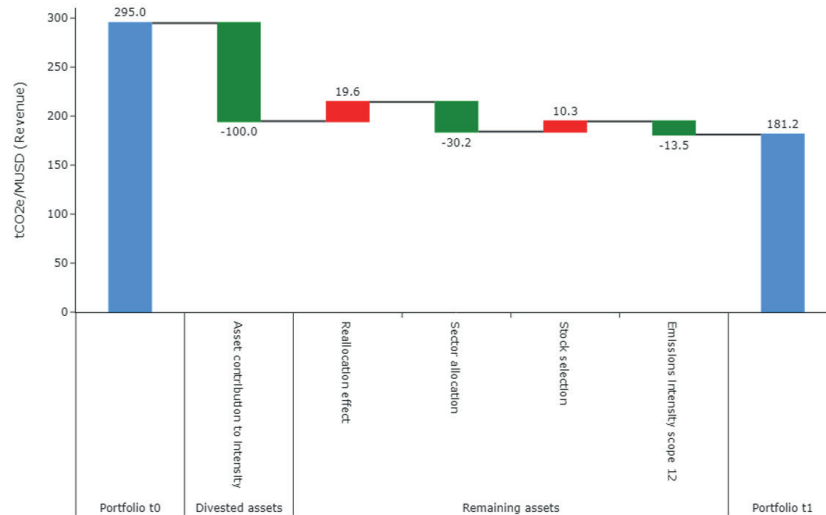
$$aw_{s(i(j)),RI,t} = \frac{\sum_{j \in \mathcal{S},RI} aw_{j,t}}{\sum_{j \in \mathcal{RI}} aw_{j,t}}$$

15 - Otherwise, the sector allocation effect for BS-LI would be impacted by the exclusion of BS-HI.

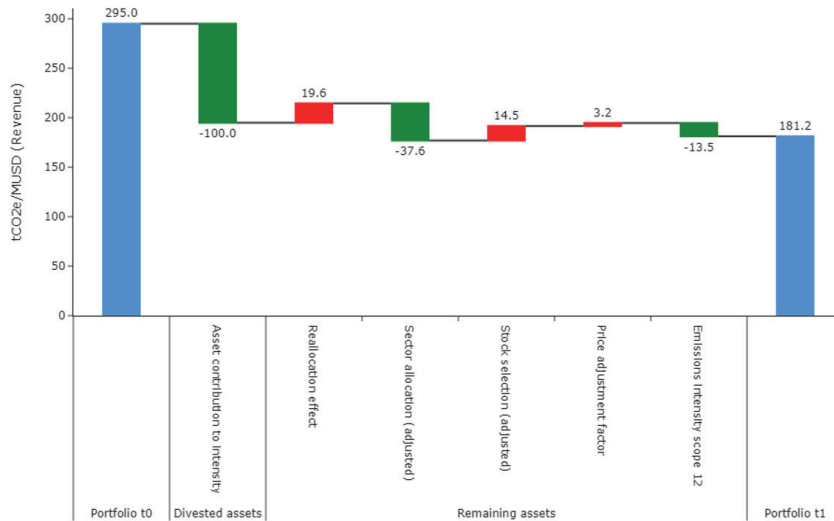
3. Combining Drivers from Existing Frameworks

Exhibit 15: Attribution of change in intensity per revenue by divestment, sector allocation, stock selection, and company intensity

a) No price adjustment of 'sector allocation' and 'stock selection' drivers



b) Price adjustment of 'sector allocation' and 'stock selection' drivers



Notes: Analysis of a fictitious portfolio using the LMDI method.

What is the Contribution of Sector Inflation and Emissions Scopes?

After observing an overall increase in companies' emissions on the first and second models, the third model revealed that their emissions intensity was decreasing slightly. However, this measure of intensity is sensitive to inflation in the prices of goods and services sold by these companies. By applying an inflation adjustment, it becomes possible to discern whether the change in intensity results from improved production efficiency (intensity per unit of production) or from inflation¹⁶. To capture this distinction, specific drivers are introduced for each scope of emissions.

$$EI_p = \sum_j w_j \cdot \underbrace{\frac{Prod_{i(j)}}{R_{i(j)}}}_{\text{Inflation}} \cdot \left(\frac{E1_{i(j)}}{Prod_{i(j)}} + \frac{E2_{i(j)}}{Prod_{i(j)}} \right)$$

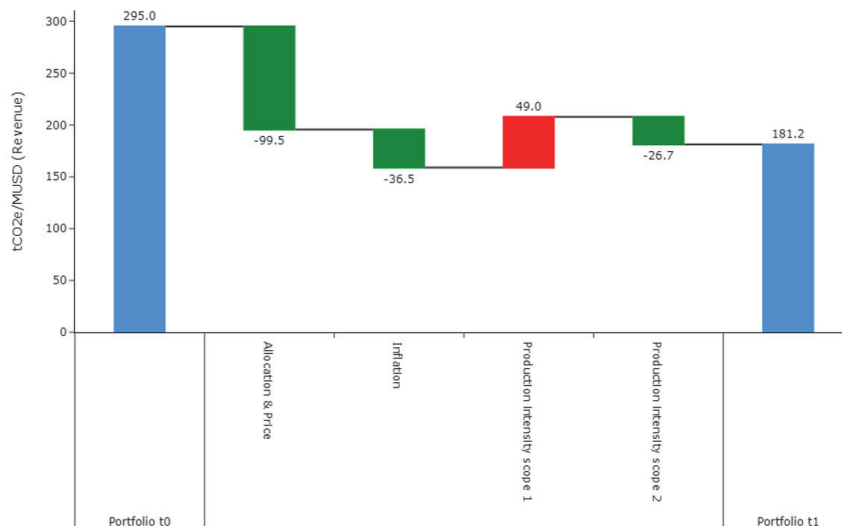
16 - As part of our example, we use individual production data from each company. Since these are not always available, it is possible to systematically adjust company revenues by a sectoral inflation factor. The World Bank Group provides for example general consumer price index inflation, but also specific Energy and Food indexes by region. For more details, see <https://www.worldbank.org/en/research/brief/inflation-database>.

3. Combining Drivers from Existing Frameworks

where $Prod_{i(j)}$ is the physical production (expressed in tonnes in our example) of the company, $E1_{i(j)}$ the company emissions on Scope 1, and $E2_{i(j)}$ on Scope 2.

This last model reveals that inflation has significantly contributed to the reduction in the portfolio's emissions intensity (per revenue), while physical intensity (measured per tonne in this example) has increased overall. When examining physical intensity, the reduction is primarily driven by Scope 2 emissions, whereas Scope 1 emissions have increased (Exhibit 16). Companies generally have less control over Scope 2 emissions, as they can reduce their own energy consumption but not the emissions intensity of the local electricity mix. By contrast, they have greater leverage over Scope 1 emissions, which are more directly tied to their operations. These distinctions between production efficiency gains and inflation on the one hand, and Scope 1 and Scope 2 on the other, could in particular help to guide the portfolio manager's engagement with companies.

Exhibit 16: Attribution of change in intensity by allocation, inflation, and scope



Notes: Analysis of a fictitious portfolio using the LMDI method.

3.3 Reconciling the Absolute Emissions, Intensity and Footprint Emissions Metrics

The previous attribution models have been used to analyse different portfolio emissions metrics in order to illustrate the flexibility of the generalisation approach. Indeed, depending on the questions, it may be more relevant to focus on certain metrics rather than others.

However, one of the advantages of the attribution approach is that it allows these metrics to be linked explicitly. More specifically, the absolute emissions of a portfolio can be expressed using intensity and footprint metrics. As presented before:

$$E_p = \sum_j \underbrace{E_j^p}_{\text{Absolute emissions (associated with instrument } j\text{)}}$$

3. Combining Drivers from Existing Frameworks

The absolute emissions associated with each instrument can be expressed as the product of the portfolio value and the carbon footprint of the company linked to that instrument.

$$E_p = \sum_j V_p \cdot w_j \cdot \underbrace{\frac{E_{i(j)}}{EVIC_{i(j)}}}_{\text{Footprint}} \\ \text{Absolute emissions}$$

Finally, company emissions can be expressed as the product of the company's emissions intensity and its revenue.

$$E_p = \sum_j V_p \cdot w_j \cdot \underbrace{\frac{E_{i(j)}}{R_{i(j)}}}_{\text{Intensity}} \cdot R_{i(j)} \cdot \underbrace{\frac{1}{EVIC_{i(j)}}}_{\text{Footprint}} \\ \text{Absolute emissions}$$

By adopting this model, all drivers influencing the three portfolio emissions metrics – absolute emissions, emissions intensity and footprint are visible – become visible. This grants a comprehensive understanding of the evolution of each metric through a single analysis.



4. Conclusion

4. Conclusion

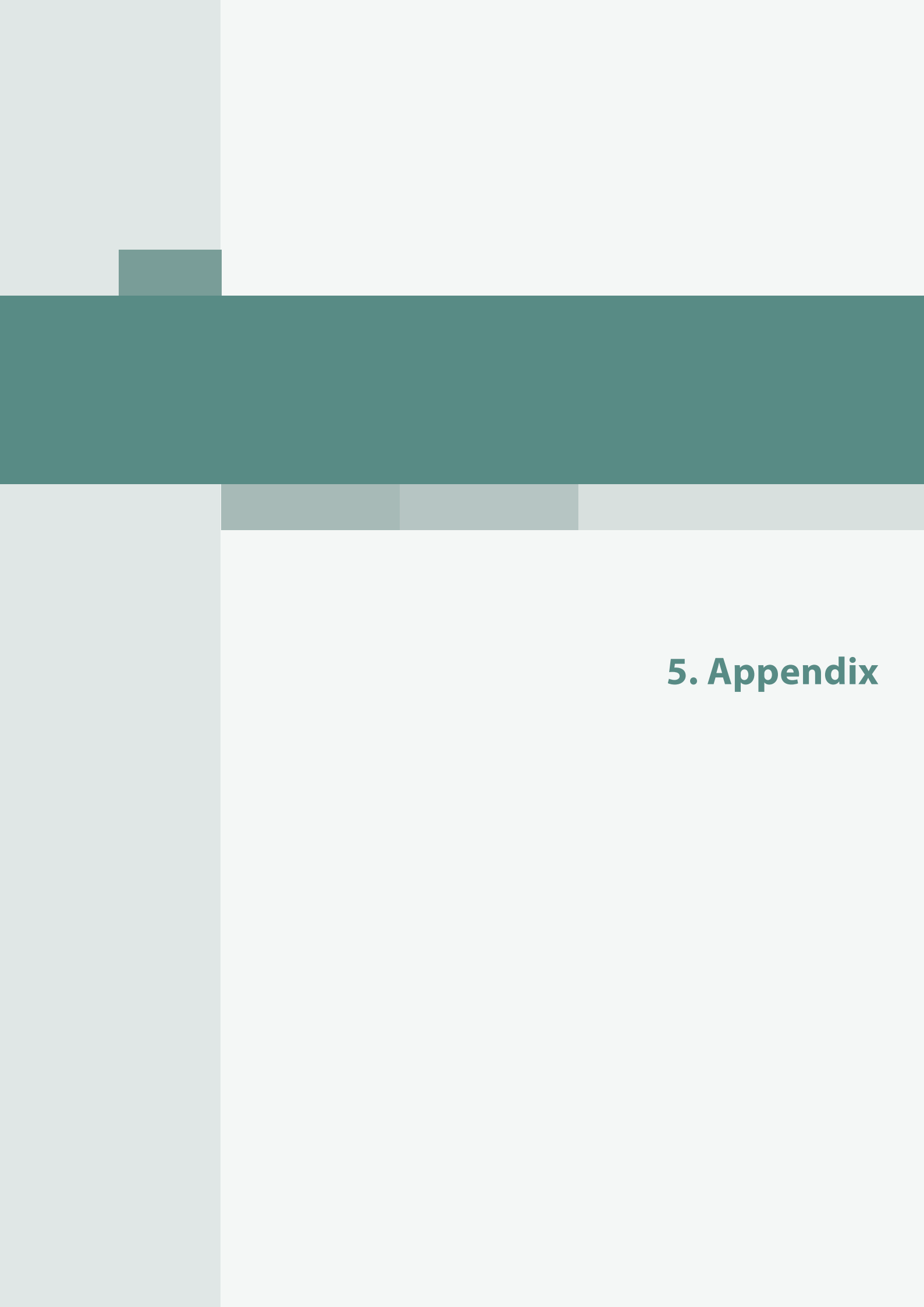
Since 2022, several attribution frameworks have been developed to help investors better understand the drivers influencing emissions metrics associated with financial portfolios (Bouchet, 2023; NZAOA, 2023; Nagy, Giese and Wang, 2023; Simmons et al., 2022). This article examines the key differences between these frameworks and explores how they can be effectively combined.

Most existing frameworks are designed for historical analysis of absolute emissions, emissions intensity, and emissions of equity portfolios. Despite their variations, the drivers identified across these frameworks can be classified into four main categories: data coverage, portfolio reallocation, economic and financial fluctuations, and company emissions.

Two principal methods are commonly used to attribute changes in emissions metrics to these drivers. The first is based on Laspeyres indicators (Laspeyres, 1871), while the second uses the logarithmic mean Divisia index (LMDI), originating from environmental economics (Ang, Zhang and Choi, 1998). For models with only two drivers, we recommend the Laspeyres method, whereas the LMDI method is more suitable for models with multiple drivers, as it avoids the inclusion of interaction terms.

Using a simplified fictitious portfolio, a first analysis demonstrates that these frameworks should be viewed not as substitutes but as complementary tools. A flexible three-step generalisation approach is then formalised to combine them and apply one of the attribution methods. This approach enables investors to assess the contributions of various drivers such as strategic asset class allocation, divestment, sector allocation, stock selection, instrument price volatility, emissions scopes, company activity, and inflation in goods and services prices to any change in portfolio emissions metrics.

By combining drivers from existing frameworks, investors can better understand the drivers behind emissions changes and distinguish between exogenous drivers, over which they have limited control (e.g., instrument price volatility), and drivers where they can exert direct influence (e.g., strategic allocation, divestment, sector allocation, stock selection) or indirect influence (e.g., on corporate emissions through engagement). In this context, attribution analysis of greenhouse gas emissions is a critical tool for constructing and monitoring a consistent climate investment strategy: the results should inform decisions related to capital allocation and corporate engagement, but also political and market advocacy (IIGCC, 2024b).



5. Appendix

5. Appendix

5.1 Generalisation of Laspeyres Indicators for More Than Three Drivers

Consider M_j as a metric at instrument level which can be expressed as a product of N drivers.

$$M_j = D_1 \cdot D_2 \cdot \dots \cdot D_N$$

Following the Laspeyres method by layers, the effect associated with driver n is:

$$E_{D_n} = \Delta D_n \cdot \prod_{k \neq n} D_{k,t0}$$

The interaction term associated with layer n (n ranging from 0 to $N-1$) is:

$$I_{ln} = \Delta D_n \cdot \left(\prod_{k=n+1}^N D_{k,t1} - \prod_{k=n+1}^N D_{k,t0} \right) \cdot \prod_{k=1}^{n-1} D_{k,t0}$$

If using the Laspeyres method without interaction terms, the effect associated with driver n is:

For $n < N-2$:

$$E_{D_n} = \Delta D_n \cdot \left(\frac{\prod_{k=n+1}^N D_{k,t1} + \prod_{k=n+1}^N D_{k,t0}}{2} \right) \cdot \prod_{k=1}^{n-1} \left(\frac{D_{k,t1} + D_{k,t0}}{2} \right)$$

$$E_{D_n} = \Delta D_n \cdot \overline{\prod_{k=n+1}^N D_k} \cdot \prod_{k=1}^{n-1} \overline{D_k}$$

For $N-2 \leq n \leq N$:

$$E_{D_n} = \Delta D_n \cdot \prod_{k \neq n} \overline{D_k}$$

5.2 Handling Zero Values in the Logarithmic Mean Divisia Decomposition Approach

To calculate the effect associated with a driver, the LMDI method involves divisions at two levels.

$$E_{D_n} = \sum_{j=1}^J \frac{M_j^{t1} - M_j^{t0}}{\ln(M_j^{t1}) - \ln(M_j^{t0})} \cdot \ln \left(\frac{D_{n,j,t1}}{D_{n,j,t0}} \right)$$

Cases where $D_{n,j,t0} = 0$ (e.g., a financial weight of a new instrument), where $D_{n,j,t1} = 0$ (e.g., a financial weight of a divested instrument), and where $M_j^{t1} = M_j^{t0}$ (i.e. no change in the instrument contribution to the metric) require a specific treatment. A first procedure recommended by Ang, Zhang and Choi (1998) is substituting a small value (10^{-10} to 10^{-20} for any zero values. However, Wood and Lenzen (2006) show that such a procedure can lead to significant errors if the data set contains a large number of zeros and/or small values.

Most of the time, when $M_j^{t1} = M_j^{t0}$, $D_{n,j,t1} = D_{n,j,t0}$ and we therefore consider that $E_{D_n} = 0$.

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To manage cases where $D_{n,j,t0} = 0$, the analytical limits approach of Ang and Liu (2007) has been used. For a certain instrument, if m drivers contain zero-changes $D_{n,j,t0} = 0$ or $D_{n,j,t1} = 0$, the m drivers contribute equally to the change in the instrument contribution to the metric.

$$E_{D_{n,j}|D_{n,j,t0}=0 \text{ or } D_{n,j,t1}=0} = \frac{M_j^{t1} - M_j^{t0}}{m}$$

5.3 Subtracting the Initial Portfolio Emissions Metric with the Laspeyres Method

The decomposition into two terms of the emissions intensity of a portfolio (or its footprint) using the Laspeyres method has the following form:

$$\Delta EI_p = \underbrace{\sum_{j=1}^J \Delta w_j \cdot EI_{j,t0}}_{\text{Weight effect}} + \underbrace{\sum_{j=1}^J \Delta EI_j \cdot w_0}_{\text{Intensity effect}} + \underbrace{\sum_{j=1}^J \Delta w_j \cdot \Delta EI_j}_{\text{Interaction term}}$$

For the 'weight' effect, it is possible to subtract the intensity (or footprint) of the portfolio from each term as follows:

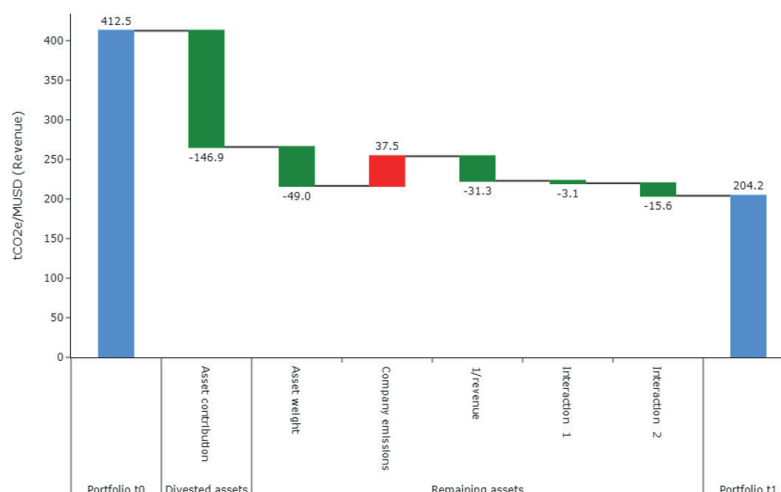
$$\sum_{j=1}^J \Delta w_j \cdot EI_{j,t0} = \sum_{j=1}^J \Delta w_j \cdot (EI_{j,t0} - EI_{p,t0})$$

This can be seen from the fact that $\sum_{j=1}^J \Delta w_j = 0$.

$$\sum_{j=1}^J \Delta w_j \cdot EI_{p,t0} = EI_{p,t0} \cdot \sum_{j=1}^J \Delta w_j = 0$$

In this way, the effect associated with a change in weight for an instrument j corresponds to an effect relating to the initial intensity of the portfolio: a red bar shows that reallocating to this instrument tends to increase the initial intensity, while a green bar tends to reduce it. Exhibit 17 shows the same result as in Exhibit 8a, but with this adjustment.

Exhibit 17: Attribution in changes in emissions intensity with initial intensity adjustment



Notes: Analysis of a fictitious portfolio using the Laspeyres method.

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5.4 Emissions Footprint Adjustment for EVIC Inflation

Inflation adjustment was introduced in the Article 7 of the European Union (EU) Commission Delegated Regulation 2020/1818¹⁷, and two calculation methods are provided by PCAF (2022)¹⁸. The first is to adjust the base year (t0) emissions footprint (backward adjustment). The second is to adjust the current footprint (t1), which is more relevant when assessing the progress against a target set in a reference year (PCAF, 2022) and is therefore adopted (Exhibit 18).

$$EF_{adjusted,p,t1} = EF_{p,t1} \cdot \frac{1}{InflationAdjustment_p}$$

where $InflationAdjustment_{p,t1} = \sum_i \left(w_{i,t1} \cdot \frac{EVIC_{i,t0}}{EVIC_{i,t1}} \right)$.

Exhibit 18: Details of calculations to adjust EVIC for inflation

	BS-HI	BS-LI	GS-HI	GS-LI	Portfolio	Unit
$E12_{i,t0}$	100,000,000	37,500,000	20,000,000	7,500,000		
$E12_{i,t1}$	87,500,000	56,250,000	17,500,000	6,250,000		
$EVIC_{i,t0}$	150,000	150,000	150,000	150,000		
$EVIC_{i,t1}$	170,000	180,000	180,000	250,000		
$EVIC_adjusted_{i,t1}$	128,444	136,000	136,000	188,898		
$w_{i,t0}$	25.0%	25.0%	25.0%	25.0%		
$w_{i,t1}$	0.0%	33.3%	33.3%	33.3%		
$InflationAdjustment_{p,t1}$	0.0	0.3	0.3	0.2	0.78	
$w_{i,t0} \cdot EVIC_{i,t0}$	166.7	62.5	33.3	12.5	275.0	tCO ₂ e/MUSD
$w_{i,t1} \cdot EVIC_{i,t1}$	0.0	104.2	32.4	8.3	144.9	tCO ₂ e/MUSD
$w_{i,t1} \cdot EVIC_adjusted_{i,t1}$	0.0	137.9	42.9	11.0	191.8	tCO ₂ e/MUSD

Notes: The adjustment factor is calculated according to PCAF (2022) and applied on final footprint (t1).

5.5 Data coverage and methodological changes

The question of the impact of changes in the coverage of emissions data, i.e., how to take into account change due “to the appearance/disappearance of emission-data coverage” (Nagy, Giese and Wang, 2023, p.170). is raised by Nagy et al (2023) and NZAOA (2023). The several options raised by the literature for taking this effect into account are discussed below and the question is extended to the impact of methodological changes from data providers.

Consider a simplified portfolio of three instruments, each representing a different data coverage case: data covered and no change in emissions (‘No change’ company), data covered but a methodological change is made between the two dates (‘Methodological change’ company), and coverage change over the period (‘Coverage change’ company) (Exhibit 19). Without adjustment, the absolute emissions associated with the portfolio fall from 33,333 tCO₂e to 31,666 tCO₂e, and the following default decomposition model is used (Exhibit 20a):

$$E_p = \sum_j N_j \cdot \underbrace{PI_j \cdot \frac{1}{EVIC_{i(j)}}}_{\text{Financial fluctuations}} \cdot \underbrace{E_{i(j)}}_{\text{Company emissions}}$$

17 - “Where the average EVIC of the constituent securities of the benchmark has increased or decreased during the last calendar year, the EVIC of each constituent shall be adjusted by dividing it by an enterprise value inflation adjustment factor. That enterprise value inflation adjustment factor shall be calculated by dividing the average EVIC of the benchmark constituents at the end of a calendar year by the average EVIC of the benchmark constituents at the end of the previous calendar year.”

18 - PCAF (2022) stresses that this adjustment metrics should be disclosed in addition to non-adjusted metrics: “financial institutions may optionally report their adjusted absolute financed emissions with the requirement that such amounts must be disclosed separately along with a description of the methodology, inputs and models utilized to calculate the corrections to EVIC. Both unadjusted and adjusted absolute finance emissions will be required for all periods disclosed in the financial reports being presented.” (p.61).

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Exhibit 19: Company and portfolio data coverage change

Company ($i(j)$)	Sector	Unit	'No change' $i \in S_{brown}$	'Methodological change' $i \in S_{brown}$	'Coverage change' $i \in S_{green}$
Emissions and economic activity	$E_{i,t0}$	(tCO ₂ e)	75,000,000	50,000,000	Not covered (b)
	$E_{i,t1}$		-	50,000,000 (a)	10,000,000 (b)
	$E_{i,t0,new_method}$	(tCO ₂ e)	-	-	-
	$E_{i,t1,new_method}$	-	-	30,000,000 (a)	-
	$R_{i,t0}$	(MUSD)	100,000	100,000	100,000
	$R_{i,t1}$		-	-	-
Financing structure	$QE_{i,t0}$		100,000,000	100,000,000	100,000,000
	$QE_{i,t1}$		-	-	-
	$PE_{i,t0}$	(USD)	1,000	1,000	1,000
	$PE_{i,t1}$		-	-	-
	$QD_{i,t0}$	-	50,000,000	50,000,000	50,000,000
	$QD_{i,t1}$	-	-	-	-
	$PD_{i,t0}$		1,000	1,000	1,000
	$PD_{i,t1}$		-	-	-
	$EVIC_{i,t0}$	(MUSD)	150,000	150,000	150,000
Portfolio allocation	$N_{i,t0}$		50,000	25,000	25,000
	$N_{i,t1}$		-	-	-
	$W_{i,t0}$	%	50.0%	25.0%	25.0%
	$W_{i,t1}$		-	-	-

Notation: see Exhibit 3 and Exhibit 4 from Section 2. Scenario: this situation represents an equally weighted portfolio for which no economic nor financial variable fluctuates. For the 'Methodological change' company, the emissions under the new methodology at t1 are 20,000,000 tCO₂ lower than the old methodology (a). For the 'Coverage change' company, the emissions were not covered in the first period but are 10,000,000 tCO₂ in the second period (b).

The first option to consider coverage change is to exclude the instruments for which the associated emissions are not covered on one of the two dates from the analysis (NZAOA, 2023). Without reweighting the remaining instruments, this results in a reduction in absolute emissions at t1 (Exhibit 20b).

An alternative is to fill in the missing values based on the sector average footprint (NZAOA, 2023), or the rest of the portfolio average footprint (Nagy, Giese and Wang, 2023). When analysing absolute emissions, whatever the adjustment, it increases the initial absolute emissions. In our case, the increase is more important using the covered instruments of the portfolio as a reference, because the 'change coverage' company belongs to the least intensive sector (Exhibit 20c/d).

Nagy, Giese and Wang (2023) and NZAOA (2023) also propose isolating the effect of these instruments by considering a specific effect related to change in data coverage.

$$Effect_{(change\ in\ data\ coverage)} = \sum_{j | e_{i(j),t0} \text{ is missing}} E_j^p - \sum_{j | e_{i(j),t2} \text{ is missing}} E_j^p$$

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With this option, the start and end values of the emissions metric are not changed, and the effect of the change in coverage is clearly identified (Exhibit 20e).

Finally, Nagy, Giese and Wang (2023) propose another way to manage data coverage change by adjusting the portfolio emissions metric with a coverage ratio, and then introducing this coverage ratio as a driver in the attribution model.

$$E_{p,coverage_adjusted} = \frac{E_p}{Coverage\ ratio}$$

Where:

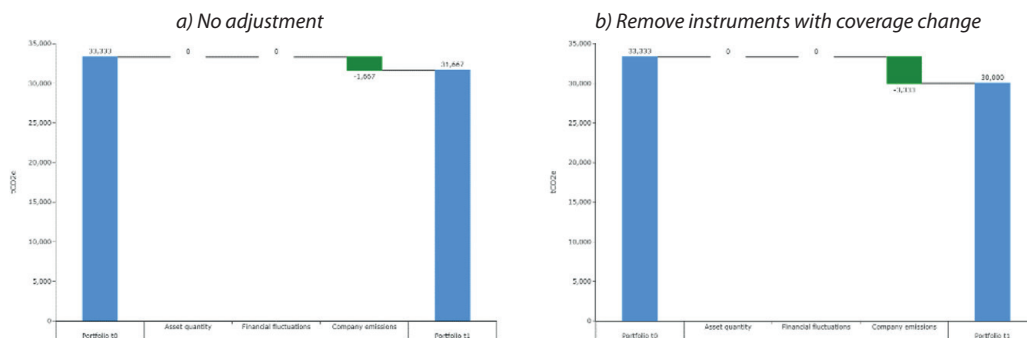
$$Coverage\ ratio = \frac{\sum_{j \in Covered\ assets} N_j \cdot PI_j}{V_p}$$

This approach (Exhibit 20f) has the same impact on the initial absolute emissions as the option to filling missing data with the average footprint of the rest of the portfolio (Exhibit 20d), but the decomposition highlight the effect of the coverage ratio change instead of associating this change with a change in corporate emissions.

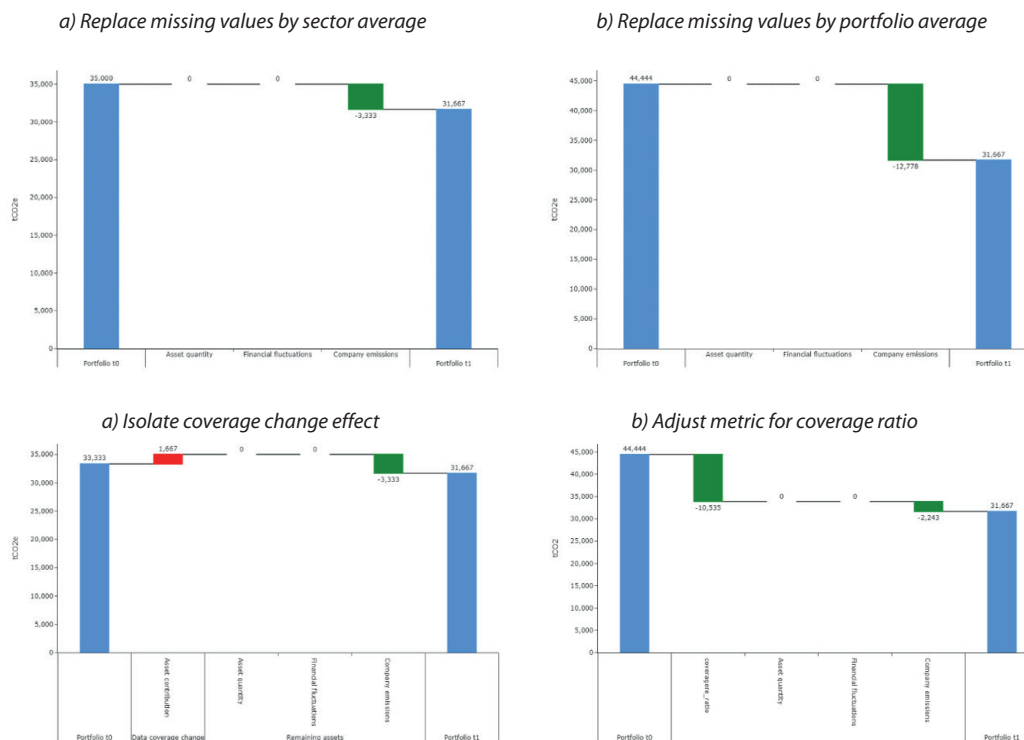
These last two options are the most likely to accurately represent the impact of a change in data coverage on a portfolio's emissions metric. The choice of adjusting or not this metric with a coverage ratio should be dictated by consistency with the choice made elsewhere to calculate the portfolio metric, particularly in reports where this appears.

However, whatever option is chosen for dealing with data coverage change, it is also important to take into account the impact of any changes in methodology. Indeed, reading the analyses presented in Exhibit 20, there is every reason to believe that the reduction in emissions can be explained by a reduction in the 'real' emissions of companies. However, this is solely due to a change in methodology (Exhibit 19).

Exhibit 20: Data coverage effect on absolute emissions



5. Appendix



Notes: Analysis of a fictitious portfolio using the Laspeyres method.

Taking into account the impact of a change in methodology requires having the value for a given date under the old and new methodologies. If this data is available (or can be estimated), it is then possible to introduce a methodological change driver, which corresponds to the difference between the value of emissions according to each methodology.

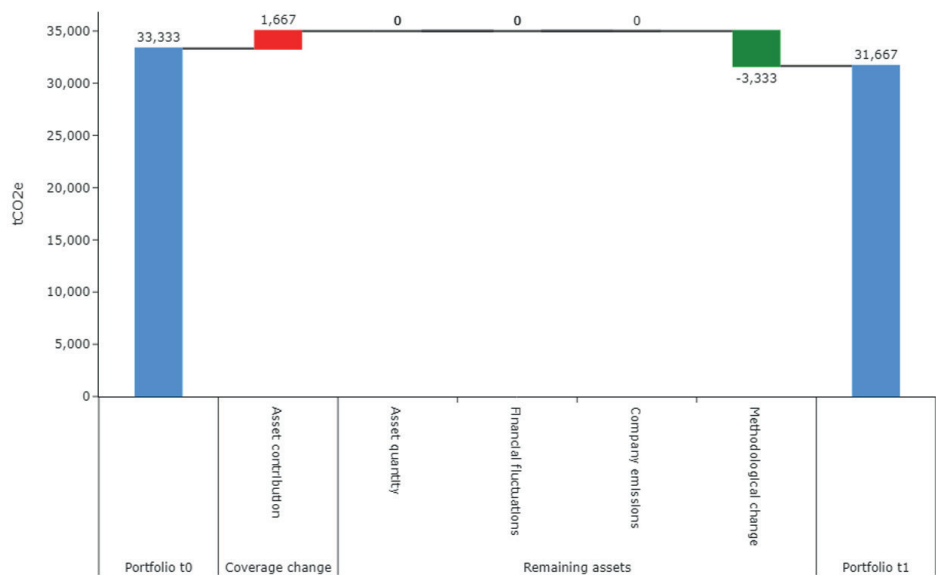
$$E_p = \sum_{j|e_{i(j),t0} \text{ is missing}} E_j^p - \sum_{j|e_{i(j),t2} \text{ is missing}} E_j^p + \sum_j \underbrace{N_j}_{\text{Financial fluctuations}} \cdot \underbrace{PI_j \cdot \frac{1}{EVIC_{i(j)}}}_{\text{Company emissions}} \cdot \left(E_{i(j)} + \underbrace{MD_{i(j)}}_{\text{Methodology change}} \right)$$

where $MD_{i(j)}$ corresponds to the difference at date t between the new and the old methodology.

In our case, the introduction of this driver makes it possible to correct the impact of the change in methodology for the 'Methodological Change' company. Finally, the change in absolute emissions is explained solely by changes in data coverage and methodology, which is more consistent with the simulated case Exhibit 21.

5. Appendix

Exhibit 21: Data coverage and methodological change effects on absolute emissions



Notes: Analysis of a fictitious portfolio using the Laspeyres method.

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