Climate Risk and Carbon Neutral Performance Attribution

In this paper, we propose a method to assess the climate risk of a portfolio, and the contribution of each portfolio component to this risk. The data needed to evaluate the risk is not only the carbon emissions of the companies but also the investments made by the companies to reduce their carbon footprint. In the second section, we propose a model that allows us to isolate in the return the component related to the cost of carbon emissions in order to calculate the attribution effects independently of the carbon footprint of the companies.

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The price of GHC emissions is almost zero today, however, it is very likely that in the near future this price will be borne directly by companies. This change entails a risk that must be measured, managed and communicated in an appropriate reporting. This risk is called climate risk, referring to the transition from an economy in which the price of emissions is zero to an economy in which companies will have to bear the costs associated with their emissions. Although this article is limited to carbon emissions, it can be extended directly to the environmental impacts of business as defined in the European Taxonomy.

This paper is organized in three sections. In the first section, we present indicators and measures of carbon emissions, and in the second we propose a methodology to measure climate risk. In the third section, we will establish a performance attribution model that isolates the impact of costs associated with carbon emissions from allocation and selection effects and bond attribution effects.

SECTION 1

In order to measure the impact of climate risk on the portfolio, it is essential to define and use a consistent measure of carbon emissions. Several metrics have been proposed to measure carbon footprint, also known as carbon intensity. The first is the Absolute Footprint, which represents a company's total emissions in tons of carbon emitted. This measure generally includes scope 1 and 2, as the integration of scope 3 can be difficult and costly.

Carbon-to-Revenue measures total emissions as a percentage of revenue. The standard unit is to express Carbon-to-Revenue in tons per million of revenue. This measure is an estimate of the company's efficiency in generating revenue per ton of carbon emitted. This indicator is the most commonly used and is available in most specialized databases. Finally, the Carbon-to-Value gives the total carbon emissions expressed as a percentage of the company's value. It is a measure of the firm's carbon efficiency in the use of capital made available to it.

The different carbon emission measures must be adjusted to the positions held in the portfolio and the benchmark. Thus, Carbon-to-Revenue can be calculated for a portfolio (CtR), for a position in a portfolio (CtR_i) and at the firm level (CtR_i^E). The portfolio carbon intensity is given by:

$$CtR = \sum_{i=1}^{N} w_i \times CtR_i$$

$w_i = V_i/V$, V_i is the value of the portfolio position and V is the value of the portfolio.

$CtR_i = V_i/V_i^E \times CtR_i^E$, V_i^E is the firm's market capitalization and CtR_i^E is the firm's carbon intensity.

Similarly, the Absolute Footprint of the portfolio is equal to the sum of the Absolute Footprint of each position in the portfolio:

$$AF = \sum_{i=1}^{N} AF_i$$

$AF_i = V_i/V_i^E \times AF_i^E$, V_i^E is the firm's market capitalization and AF_i^E is the firm's Absolute Footprint.

Example 1

The market capitalization of firm E is $V_i^E = 7{,}110$ million.

The turnover of firm E is $REV_i^E = 52{,}100$ million.

The value of the position in the portfolio is $V_i = 4$ million.

The carbon intensity is $CtR_i^E = 15$, *i.e.*, 15 tons emitted per million in sales.

The carbon intensity of the position in the portfolio is equal to

$$CtR_i = V_i/V_i^E \times CtR_i^E = 4/7{,}110 \times 15 = 0.84.$$

The Absolute Footprint of the company is equal to

$$AF_i^E = CtR_i^E \times REV_i^E = 15 \times 52{,}100 = 781{,}500\ tons.$$

And the Absolute Footprint of the position is

$$AF_i = V_i/V_i^E \times AF_i^E = 4/7{,}110 \times 781{,}500 = 439.7.$$

Although actual carbon emissions are not currently a burden on business, it seems inevitable that carbon emissions will be charged to business. The price of a ton of carbon could reach \$300 per ton in 2028. We can thus associate an annual cost (CC_i^E) equal to the Absolute Footprint (AF_i^E) multiplied by the cost of emitting a ton of carbon (*C*) with firm carbon emissions:

$$CC_i^E = AF_i^E \times C$$

The cost incurred by the portfolio position is

$$CC_i = V_i/V_i^E \times AF_i^E \times C$$

Using the data from Example 1, and assuming a price of \$300 per ton emitted, we obtain for the company and the portfolio position

$$CC_i^E = AF_i^E \times C = 781{,}500 \times 300 = 234{,}450{,}000\ \$$$

and

$$CC_i = V_i/V_i^E \times AF_i^E \times C = 4/7{,}110 \times 781{,}500 \times 300 = 131{,}899\$$$

This represents a cost expressed as a percentage of the

$$RC_i = CC_i/V_i = 131{,}899/4{,}000{,}000 = 3{,}3\%$$

This means a significant annual return (<0) that must be taken into account in the analysis of portfolio risk and performance.

SECTION 2

In this section, we will focus on measuring the climate risk borne by a portfolio. The climate risk is defined as the negative impact on the portfolio's return induced by the introduction of a carbon tax. Indeed, the introduction of such a tax will have a negative effect on firms that emit large quantities of carbon, and that have not yet invested to reduce these emissions. There are therefore two important parameters to take into account: the current volume of emissions, and the investments made to reduce future emissions. Current emissions are measured either by carbon intensity or by absolute footprint. The investments made to reduce emissions can be measured by the expected rate of emissions decline.

In order to measure the impact of this taxation on the value and to calculate the associated return (<0), we will draw inspiration from the approach of Modigliani and Miller (1963). Indeed, a company that does not engage in a process of de-carbonization of its emissions will have to bear taxation in the following years equivalent to the number of tons emitted multiplied by the cost of carbon emissions. Inspired by Modigliani and Miller's theorem (1958) adapted to corporate taxation (1963), we can assume that the value of the economic asset of the carbon emitting firm is equal to the value of the economic asset of a non-emitting firm minus the present value of the annual cost of carbon emissions. The variation in value between the emitting company and the equivalent carbon-neutral company gives the return (<0) associated with emissions. This approach also has the advantage of allowing the integration of investments made by the company in order to be part of the energy transition.

Hence, the present value (VCC_i^E) of future carbon emissions for a firm that does not invest in the energy transition is given by:

$VCC_i^E = \sum_{t=1}^{T} CC_i^E/(1+r)^t$, r being the long-term interest rate.

If the firm does not invest to reduce its emissions, then the present value of the costs associated with carbon emissions is given by :

$$VCC_i^E = CC_i^E/r$$

Moreover, if we assume that the firm invests in order to achieve a constant annual decrease (d) in its emissions, we have

$$AF_{i,1}^E = AF_{i,0}^E \times (1-d)$$

That is

$$AF_{i,t}^E = AF_{i,0}^E \times (1-d)^{t-1}$$

Thus, an annual decrease of 25% implies a reduction of about 70% of the emissions after five years. Assuming that this reduction in carbon emissions will be continued over a very long period, we obtain the present value of the cost of emissions adjusted to the investments in reducing the carbon footprint

$$VCC_i^E = \sum_{t=1}^{T} AF_{i,0}^E \times (1-d)^{t-1}/(1+r)^t$$

$$VCC_i^E = AF_{i,0}^E \times C \ /(r+d)$$

Since the portfolio holds only a fraction (V_i/V_i^E) of the firm, the present value of the carbon emission cost associated with a position in the portfolio is given by :

$$VCC_i = V_i/V_i^E \times VCC_i^E = AF_{i,0} \times C \ /(r+d)$$

We can therefore measure the present value of the costs that will be borne by the company when carbon emissions are taxed. When the introduction of such a tax is announced, investors will integrate the present value of these future negative cash flows in the value of the company, and the stock price will suffer a decrease equal to the present value of these costs divided by the market capitalization of the company. This gives a negative return:

$$RC_i = VCC_i^E/V_i^E$$

This cost expressed as a percentage is independent of the position in the portfolio, in fact

$$RC_i = VCC_i/V_i = \left[V_i/V_i^E \times VCC_i^E\right]/V_i = VCC_i^E/V_i^E$$

<u>Example 2</u>

Consider a portfolio of four stocks, the interest rate is 2 percent.

The turnover, the market capitalization, the carbon to revenue, the emission decrease rate and the cost per ton of carbon are given.

We can then calculate the absolute footprint of each company as well as the present value of the carbon costs and the associated return (<0) (see Table 1).

We see that firm 3, which has an absolute footprint of 499,800 tons, has a lower climate risk (-4.56%) than firm 4, which has an absolute footprint of 312,450 tons. The magnitude of Firm 4's risk (-7.32%) is mainly due to Firm 4's low investment in reducing its carbon footprint.

Example 2 highlights the climate risk of each firm, which is the impact on the return of the introduction of a carbon tax. We can then calculate the contribution of each position to the total carbon risk of the portfolio and

Table 1

Asset	**REV_i^E (000,000)**	**V_i^E (000,000)**	**CtR_i^E**	***d***	***C***	**AF_i^E**	**VCC_i^E (000,000)**	**RC_i**	**Contrib RC_i**
1	5,210	7,110	15	10%	-300	78,150	-195.38	-2.75%	-0.85%
2	15,630	13,330	20	20%	-300	312,600	-426.27	-3.20%	-0.74%
3	8,330	8,890	60	35%	-300	499,800	-405.24	-4.56%	-0.70%
4	20,830	10,670	15	10%	-300	312,450	-781.13	-7.32%	-2.25%
								-4.54%	**-4.54%**

thus, for example, identify the top 5 riskiest positions.

In the next section we will integrate the notion of return of a non-emitting firm in order to propose a carbon-adjusted attribution model. Such a model allows us to identify the positions that are most exposed to climate risk relative to its benchmark.

SECTION 3

In this section, we present a return attribution model that quantifies the differences in carbon exposure between portfolio and benchmark positions. This will make it possible to determine the allocation and stock selection effects independently of the climate risk. Regardless of the asset class, the objective of the performance attribution models is to explain the active return of the portfolio, which is equal to the difference between the return of the portfolio and the benchmark, *i.e.,*

$$\Delta R = R - \underline{R}^{\text{i}}$$ [3]

In order to isolate the impact of carbon emissions, we will assume that it is possible to calculate the return of an equivalent non-carbon emitting firm (*R*'). Such a firm, strictly equivalent to the observed firm, will have a higher return because it does not bear any cost related to its carbon emissions. The observed return (*R*) is equal to the return of the equivalent firm (*R*') minus the return (<0) associated with carbon emissions (*RC*). The active return relative to the benchmark is made up of a component linked to the climate risk exposures (which we will call the carbon effect), and another one depending on the active management decision process. For the sake of clarity, we will limit ourselves to active management involving allocation and selection. The active return is

$$\Delta R = Carbon\ Effect + \left(R' - \underline{R}'\right) \quad . \quad (1)$$

The carbon effect reflects the difference in exposure to climate risk. The magnitude of this risk will depend, on the one hand, on the emissions of companies and their efforts to reduce their emissions, and, on the other hand, on the cost of carbon emissions. However, it should be noted that this cost can be direct and observable, such as the price of carbon certificates, or it can also be indirect, such as the consequences in terms of image for the firm or the payment of higher interest rates. All these costs, direct or indirect, will be called the carbon cost.

The carbon-neutral asset return will then be explained by the standard effects of attribution as developed in the models of Brinson and Fachler or Brinson, Hood and Beebower. It should be noted that the carbon-neutral asset return can also be explained by other effects, such as factor effects or rate effects.

Measuring the Carbon Effect

To calculate the carbon effect in equation 1, we need to compare the Absolute Footprint of the portfolio position with the Absolute Footprint of a position in the benchmark. A portfolio with a larger absolute footprint than its benchmark is then exposed to a higher climate risk. In order to compare the carbon footprints, it is necessary to calculate the carbon footprint of the benchmark, which requires a transformation of the weights in the benchmark into amounts invested. We will assume that the benchmark is a portfolio whose value is equal to the value of the portfolio. Thus, the weight of the benchmark can be transformed into the amount invested, *i.e.*

$\underline{V_i} = \underline{w_i} \times V$, V being the total value of the portfolio and $\underline{w_i}$ the weight of the stock in the benchmark

From then on, the position-adjusted Absolute Footprint in the portfolio (AF_i) and in the benchmark ($\underline{AF_i}$) are respectively given by,

$$AF_i = V_i / V_i^E \times AF_i^E \text{ , et } \underline{AF_i} = \underline{V_i} / V_i^E \times AF_i^E$$

The carbon effect of a position in the portfolio should be proportional to the absolute footprint difference multiplied by the cost of carbon emissions.

$$\Delta AF_i = \left(AF_i - \underline{AF_i}\right) \times C$$

The efforts made by companies to reduce their emissions will be directly taken into account by the absolute footprint, which will evolve during the analysis period.

Given that the contribution to the return of a position is equal to the P&L of this position divided by the value of the portfolio, we can thus calculate the contribution to the active return of a choice of exposure to higher or lower carbon emissions, *i.e.*,

$$ContribCarbonEffect_i = RC_i = \frac{(AF_i - \underline{AF_i}) \times C}{V}$$

Practically, this effect can be calculated from available data, namely the Carbon to Revenue ratio (CtR_i^E), revenue (REV_i^E), market capitalization (V_i^E), and the cost per ton of carbon(C).

The carbon effect of a portfolio or sub-portfolio corresponding to a clustering criterion is equal to the sum of the contributions,

$$CarbonEffect = \sum_{i=1}^{N} \frac{(AF_i - \underline{AF_i}) \times C}{V} = \sum_{i=1}^{N} RC_i \,. \quad (2)$$

Example 3

Consider the portfolio shown in Example 2.

The revenue, market capitalization, carbon to revenue and cost per ton of carbon are shown in Table 2.

The positions in the portfolio and the contribution to the carbon effect are shown in Table 3.

We observe that the portfolio has an absolute footprint of 344 against 302 for the benchmark. The carbon footprint of the portfolio being higher than the benchmark, the carbon effect of the portfolio is negative and equal to – 0.015% per year.

The attribution model (Equation 1) isolates the carbon effect in order to explain the active return independently of the firms' carbon emissions. The second term of the equation $R' - \underline{R}'$ is the active return of a portfolio composed of non-carbon emitting firms. Since carbon emissions have a cost (C<0), the return of the non-carbon emitting firm is greater than the return of the firm.

We will now determine the adjustments that need to be applied to the return (R_i) of the securities in order to determine the return (R'_i) of an equivalent non-issuing firm. This adjusted return will then be used to compute the effects in attribution models, either Brinson-type models or bond attribution models.

In equation 1 of the model, we will replace the carbon effect given by equation 2

$$R - \underline{R} = R' - \underline{R}' + \sum_{i=1}^{N} \frac{(AF_i - \underline{AF_i}) \times C}{V}$$

Table 2

Asset	REV_i^E (000,000)	V_i^E (000,000)	CtR_i^E	C	AF_i^E
1	5,210	7,110	15	-300	78,150
2	15,630	13,330	20	-300	312,600
3	8,330	8,890	60	-300	499,800
4	20,830	10,670	15	-300	312,450

Table 3

Asset	V_i (000)	w_P	w_B	AF_i^1	$\underline{AF_i}$	$(AF_i-\underline{AF_i})\times C$	Carbon Effect[2]
1	4000	30.8%	18.0%	43.97	16.50	-8,240	-0.015%
2	3000	23.1%	10.0%	70.35	19.56	-15,238	-0.027%
3	2000	15.4%	40.0%	112.44	187.55	22,533	0.041%
4	4000	30.8%	32.0%	117.13	78.15	-11,694	-0.021%
				344	**302**	**-12,639**	**-0.023%**

We use the following relations

$$AF_i = V_i/V_i^E \times AF_i^E \text{ et } \underline{AF_i} = \underline{V_i}/V_i^E \times AF_i^E$$
$$w_i = V_i/V \text{ et } \underline{w_i} = \underline{V_i}/V$$

In order to obtain a new relationship for the active return of the portfolio

$$\sum_{i=1}^{N} w_i \times R_i - \sum_{i=1}^{N} \underline{w_i} \times \underline{R_i} = \left(\sum_{i=1}^{N} w_i \times R'_i + \sum_{i=1}^{N} w_i \times \frac{AF_i^E \times C}{V_i^E}\right) - \left(\sum_{i=1}^{N} \underline{w_i} \times \underline{R'}_i + \sum_{i=1}^{N} \underline{w_i} \times \frac{AF_i^E \times C}{V_i^E}\right)$$

This expression gives the relationship for the returns of equivalent non-carbon emitting firms

$$R'_i = R_i - \frac{AF_i^E \times C}{V_i^E} \text{ et } \underline{R'}_i = \underline{R_i} - \frac{AF_i^E \times C}{V_i^E}. \quad (3)$$

We can therefore use these adjusted returns to calculate allocation effects independently of carbon emissions for all portfolio types. Thus, in the particular case of an active decision process based on allocation and selection, the effects are

$$Allocation = \sum_{i=1}^{N} (w_i - \underline{w_i}) \times (R'_i - \underline{R'}) \text{ et } Selection = \sum_{i=1}^{N} w_i \times \left(R'_i - \underline{R'_i}\right)$$

Although we present only allocation and selection effects, adjusted returns can also be used in allocation models for portfolios investing in different financial asset classes.

Example 4

For a portfolio that invests in four different sectors, the positions in sectors A, B, C, and D are presented in table -1- in the appendix. For each sector, we have calculated the contribution to the carbon effect and the returns of the equivalent non-carbon emitting firms (see Table 4).

We can see from this example that the absolute footprint of the portfolio (1,862) is higher than that of the benchmark (1,668), so the portfolio is more exposed to carbon emissions. This higher exposure results in a negative carbon effect of -0.105 percent. The allocation and selection effects are calculated on the adjusted returns and are therefore not influenced by carbon emissions.

CONCLUSION

There is no doubt that in the next few years, companies that emit a lot of carbon and do not invest in reducing their emissions will face taxes or fines. The introduction of taxes will have an effect on the future results of companies, and will lead to a loss of value for the shares of these same companies. It is therefore crucial to introduce KPIs to monitor these risks and quantify their impact on portfolio returns. In this paper, we have proposed a measure of climate risk based on the company's carbon emissions, the investments made to reduce these emissions and the taxation policy.

When such a tax is introduced, it will become important to isolate the carbon emission effects from the standard allocation effects, whether it is the Brinson-type allocation or the bond allocation. The third section of this paper proposes a model that isolates the emissions-related component of the return in order to propose an independent measure of attribution effects.

Table 4

Sector	V_i (000)	w_i	$\underline{w_i}$	AF_i	$\underline{AF_i}$	R_i	$\underline{R_i}$	Carbon effect	Allocation	Selection
A	13,000	23.4%	15.0%	344	302	4.92%	7.16%	-0.023%	0.410%	-0.591%
B	11,400	20.5%	30.0%	128	189	1.04%	0.71%	0.033%	0.219%	0.068%
C	8,200	14.7%	25.0%	344	571	1.44%	1.45%	0.122%	0.069%	0.002%
D	23,000	41.4%	30.0%	1,046	607	2.72%	2.70%	-0.237%	0.049%	0.120%
	55,600	**100%**	**100%**	**1,862**	**1,668**	**2.70%**	**2.46%**	**-0.105%**	**0.747%**	**-0.401%**

APPENDIX

Table A1

Sector A	Asset	V_i^E (000,000)	AF_i^E	CtR_i^E	C	w_i	$\underline{w}_i$	AF_i	$\underline{AF}_i$	R_i	$\underline{R}_i$	R'_i	$\underline{R}'_i$	Contribution Carbon Effect
	1	7,110	78,150	15	-300	30.8%	18.0%	43.97	16.50	8.00%	8.00%	8.33%	8.33%	-0.015%
	2	13,330	312,600	20	-300	23.1%	10.0%	70.35	19.56	-2.00%	-2.00%	-1.30%	-1.30%	-0.027%
	3	8,890	499,800	60	-300	15.4%	40.0%	112.44	187.55	12.00%	12.00%	13.69%	13.69%	0.041%
	4	10,670	312,450	15	-300	30.8%	32.0%	117.13	78.15	3.50%	3.50%	4.38%	4.38%	-0.021%
		40,000				**1.00**	**1.00**	**344**	**302**	**4.92%**	**7.16%**	**5.72%**	**8.25%**	**-0.023%**

Sector B		V_i^E (000,000)	AF_i^E	CtR_i^E	C	w_i	$\underline{w}_i$	AF_i	$\underline{AF}_i$	R_i	$\underline{R}_i$	R'_i	$\underline{R}'_i$	Contribution Carbon Effect
	1	30,000	200,000	10	-300	22%	30%	16.67	33.36	1.00%	1.00%	1.20%	1.20%	0.009%
	2	16,500	144,000	8	-300	39%	20%	38.40	29.11	2.00%	2.00%	2.26%	2.26%	-0.005%
	3	29,000	150,000	5	-300	13%	20%	7.76	17.26	-1.00%	-1.00%	-0.84%	-0.84%	0.005%
	4	11,000	240,000	6	-300	26%	30%	65.45	109.18	0.70%	0.70%	1.35%	1.35%	0.024%
		86,500				**1.00**	**1.00**	**128**	**189**	**1.044%**	**0.71%**	**1.38%**	**1.05%**	**0.033%**

Sector C		V_i^E (000,000)	AF_i^E	CtR_i^E	C	w_i	$\underline{w}_i$	AF_i	$\underline{AF}_i$	R_i	$\underline{R}_i$	R'_i	$\underline{R}'_i$	Contribution Carbon Effect
	1	40,000	240,000	30	-300	10%	10%	4.80	8.34	3.00%	3.00%	3.18%	3.18%	0.002%
	2	70,000	600,000	40	-300	17%	20%	12.00	23.83	-4.00%	-4.00%	-3.74%	-3.74%	0.006%
	3	20,000	1,200,000	40	-300	24%	30%	120.00	250.20	4.50%	4.50%	6.30%	6.30%	0.070%
	4	13,500	700,000	50	-300	49%	40%	207.41	288.30	1.50%	1.50%	3.06%	3.06%	0.044%
		143,500				**1.00**	**1.00**	**344**	**571**	**1.439%**	**1.45%**	**2.70%**	**2.68%**	**0.122%**

Sector D		V_i^E (000,000)	AF_i^E	CtR_i^E	C	w_i	$\underline{w}_i$	AF_i	$\underline{AF}_i$	R_i	$\underline{R}_i$	R'_i	$\underline{R}'_i$	Contribution Carbon Effect
	1	32,000	300,000	10	-300	4%	10%	9.38	15.64	1.50%	1.50%	1.78%	1.78%	0.003%
	2	40,000	750,000	30	-300	17%	30%	75.00	93.83	3.00%	3.00%	3.56%	3.56%	0.010%
	3	30,000	2,500,000	50	-300	43%	30%	833.33	417.00	2.50%	2.50%	5.00%	5.00%	-0.225%
	4	50,000	800,000	20	-300	35%	30%	128.00	80.06	3.00%	3.00%	3.48%	3.48%	-0.026%
		152,000				**1.00**	**1.00**	**1046**	**607**	**2.717%**	**2.70%**	**4.08%**	**3.79%**	**-0.237%**

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ENDNOTES

[1] For Asset 1, footprint is equal to 78,150 x 4,000 / 7,110,000 = 43.97.

[2] As the total value of the portfolio is 55,600,000, the Contribution to Carbon Effect for asset 1 is equal to (43.97 – 16.50) x (– 300) / 55,600,000 = – 0.015%

[3] We use the common notation which consists in underlining the return of the benchmark.