Climate scenarios and carbon neutrality: the investors/companies nexus

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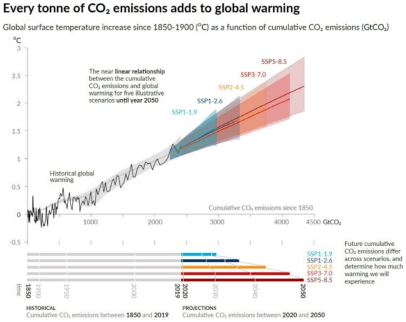
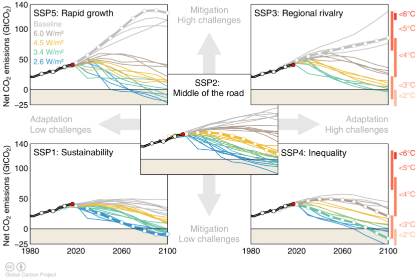
Climate scenarios

- In its simplest form: projection of anthropogenic carbon emissions over a period of time: **carbon budget**.
- More sophisticated models (such as Shared Socio-economic Pathways, IPCC): addition of socio-economic parameters.



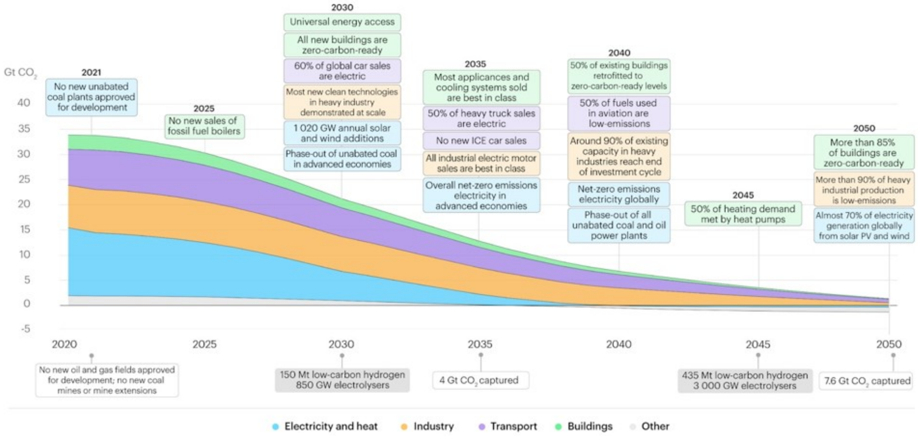
Carbon budgets, IPCC



Shared Socio-economic Pathways, *IPCC & Global Carbon Project*

Global carbon neutrality by 2050

- Reaching net zero emissions globally (carbon neutrality) by 2050 means that global warming is limited to less than 2°C, with emissions being halved by 2030.



Net Zero Scenario, *International Energy Agency*

Status of Net Zero targets in 2022

- Since 2015, **91% of the world's GDP** is covered by Net Zero pledges: 83% of the world's GHG emissions (Net Zero Tracker, 2022).
- At the subnational level, most Net Zero targets come from **high-income countries**.
- 58% of **companies headquartered in Europe** have Net Zero targets, a figure much higher than companies with American (36%) or Asian (20%) headquarters.

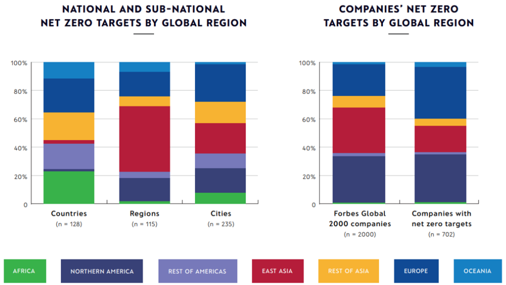
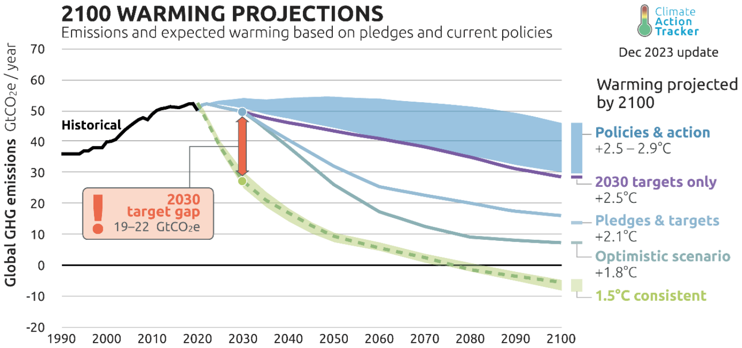


Figure 2: Breakdown of net zero targets by UN region classification for national and sub-national governments (left panel) and for companies (right panel). For companies, the breakdown of all Forbes 2000-listed companies by their headquarters location is also presented for comparison.

Source: Net Zero Tracker

Status of Net Zero targets in 2022

- Net Zero pledges more robust and credible, but insufficient to keep global warming below 2°C (Boehm et al., 2023).
- Medium-term targets are the least ambitious.
- Policies and actions could lead to a global warming of +3°C by the end of the century.



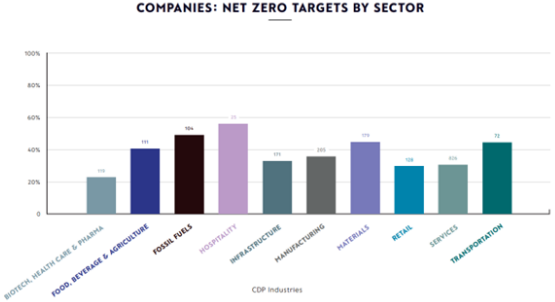
Source: Climate Action Tracker

Low-carbon targets of companies

- Third-party verification platforms (Science-Based Targets initiative, ACT) have become very popular for the credibility of the targets.

The credibility of a low-carbon target: '4P' criteria

- Pledge: publicly declared, specific timeline with interim targets.
- Plan: existence of clear plans with concrete operational ramifications.
- Proceed: immediate action once the pledge is published.
- Publish: progress reports should be frequent and publicly available.

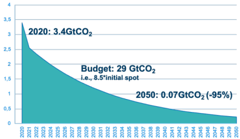


Source: Net Zero Tracker

Aligning a portfolio to Net Zero

- Financial portfolios can also align with metrics such as Implied Temperature Ratings.
- The Alignment Cookbook (Raynaud et al., 2020): methodology for translating global scenarios into alignment metrics.
- More straightforward approach: a carbon budget becomes a constraint for the allocation of assets (Bolton, Kacperczyk, and Samama, 2022).

Figure 2: Carbon emissions reduction that mimics the required path to achieve carbon neutrality by 2050 on MSCI Europe



Assumptions: 25% initial haircut followed by an 8% geometric reduction; emissions are constant

Bolton, Kacperczyk, and Samama, 2022

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Motivations

- The alignment strategy of a company an important issue when the current objective is to accelerate the transition.
- Existing theoretical models have not modeled the impact of committing to a low-carbon target on stock prices.

Asset prices equilibrium

Low-carbon targets of companies and investor preferences: **how can more companies commit to low-carbon strategies?**

Climate risk of alignment strategies

Existence of a climate risk premium: **is there a lower financial risk when a company commits to a low-carbon target?**

Alignment strategies and portfolio allocation

- We bring a theoretical and empirical contribution to the literature on low-carbon targets for companies and investors.

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- We apply the concepts of climate scenario and alignement to an economic model in two phases:
  - In the first phase, firms must take a strategic decision on aligning to a low-carbon scenario. We introduce the concept of **decarbonization ability** as a key parameter in the firms' decisions.
  - In a second phase, after targets are publicly announced, investors make their portfolio allocations based on the firms' decisions, which are translated into a climate risk premium.

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  - In a second phase, after targets are publicly announced, investors make their portfolio allocations based on the firms' decisions, which are translated into a climate risk premium.
- We also empirically illustrate the existence of a climate risk premium for firms that do not commit to a low-carbon target within certain industrial sectors.

Existing literature

- Committing to a low-carbon target serves different objectives: lowering impact on climate change, to increase customer demand, and to attract investors: Flammer, 2012; Chen, Kumar, and Zhang, 2019; Bolton and Kacperczyk, 2021.
- For an investor, a firm's commitment is a long-term indicator of its financial risk Slawinski et al., 2017.
- Multi-stakeholder initiatives (SBTi, ACT, Climate Action 100+), play an important role in accelerating the commitment of firms to low-carbon targets.
- Several theoretical models use utility functions integrating climate preferences: Pástor, Stambaugh, and Taylor, 2021; Pedersen, Fitzgibbons, and Pomorski, 2021; Avramov et al., 2022; Zerbib, 2022.

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Climate scenarios using carbon budgets

- Climate scenario (low-carbon pathway): for a carbon budget, we determine a decarbonization rate.

$$\int_0^\infty E_t \, \mathrm{d}t = \int_0^\infty E_0(1-\tau)^t \, \mathrm{d}t = C \tag{1}$$

E_t, $E_{t=0}$: global emissions at t and at $t=0$
C: global carbon budget
τ: decarbonization rate

- We define a reference pathway, the benchmark target, compatible with a well below 2°C carbon budget C with a **benchmark decarbonization rate τ_B**:

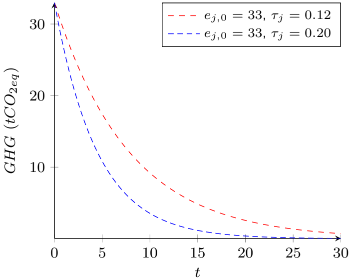
Definition (*Benchmark low-carbon target*)

Cumulative emissions must be equal to the carbon budget:

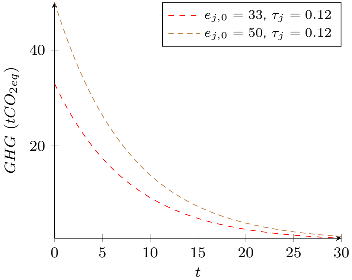
$$\sum_{j=1}^{M} \sum_{t=0}^{T} e_{j,0} \cdot (1-\tau_B)^t = C$$

Example of decarbonization pathway

(a) Heterogeneous efforts with the same initial level of emissions



(b) Homogeneous efforts with heterogeneous levels of initial emissions



Examples of low-carbon pathways

Model outline

M public companies
Risk free asset with return r_f
Carbon budget C

t

Company j

Ability a_j
Initial profit: $\pi_{j,0}$
Return of stock at time 1: r_j

Investor i

Relative risk aversion γ_i
Environmental preferences δ_i
Portfolio gross return w_i

EVALUATION PHASE

Choice of low- carbon target according to a_j
- High ambition rate: $\tau_j \geq \tau_B$
- Benchmark decarbonization rate: τ_B

The investor can estimate the ability a_j of each firm

OPERATIONAL PHASE

$t = 0$

Announcement of low-carbon strategy:
- **Type H**: abatement rate $\tau_j \geq \tau_B$
- **Type B**: abatement rate τ_B
- **Type N**: no ambition, no carbon target is set

Composition of the stock market: s_H, s_B, s_N

Portfolio allocation according to risk aversion and environmental preferences

Portfolio allocation $\boldsymbol{x}_i$

Market clearing condition: equilibrium price

$t = 1$

Low-carbon targets are/ are not achieved

Decarbonization ability

- We introduce the concept of **decarbonization ability**, labeled a_j for firm j: companies' capacities to abate their emissions.
- In practise, it is an endogenous variable with an underlying set of characteristics: climate governance, green CAPEX, level of emissions, competition, etc.
- Companies should be evaluated on the trajectory of their emissions and on the credibility of achieving the low-carbon targets they set.

Evaluation phase: selecting a target

- Objective of firms: increase their value (Robert, 2023) by **maximizing expected revenue** (Cornell and Damodaran, 2020):

$$E[\pi_{1,j}] = \begin{cases} \pi_{0,j}(1 + g_j + \lambda_j\ \tau_B) & \text{for type B} \\ \pi_{0,j}(1 + g_j + \lambda_j\ \tau_j) & \text{for type H} \\ \pi_{0,j}(1 + g_N) & \text{for type N} \end{cases}$$

$$\lambda_j = \begin{cases} \lambda\ (1 - \tau_B) & \text{for type B} \\ \lambda & \text{for type H} \end{cases}$$

$\pi_{0,j}, \pi_{1,j}$: profits of company j at $t = 0, 1$
g_j: profit growth rate of company j
g_N: profit growth rate of a type N company
$\lambda \in]0, 1]$: constant probability for a type H company to achieve its target

- The decarbonization rate of a type H company depends on its ability:

$$\tau_j = (a_j + \kappa)^2 \quad \text{with } \kappa \in]0, 1[$$

Evaluation phase: when a firm commits

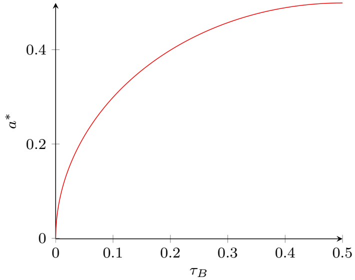
When firm j decides to commit, it will choose to be of type H if:

$$\pi_{0,j}(1 + g_j + \lambda\ (a_j + \kappa)^2)\ \geq\ \pi_{0,j}(1 + g_j + \lambda\ \tau_B\ (1 - \tau_B))$$

Definition

We define the **decarbonization ability threshold a^***:

$$a^* = -\kappa + \sqrt{\tau_B\ (1 - \tau_B)}$$



Benchmark decarbonization rate constraint on ability of firms ($\kappa = 0.001$)

Evaluation phase: composition of the stock market

- The indifference condition between being a type B or a type N company is:

$$g_N = g_j + \lambda\ \tau_B\ (1 - \tau_B)$$

- For a firm with high abilities, we assume there is always an incentive to announce a low-carbon target:

Assumption

For firm j, if $a_j > a^*$ then $g_j > g_N - \lambda\ \tau_B\ (1 - \tau_B)$.

- Market distribution:

$$\begin{cases} s_B + s_N = a^* \\ s_H = 1 - a^* \end{cases} \tag{2}$$

Portfolio allocation: risk aversion and climate preference

- At the beginning of the operational phase:
  - Low-carbon target announcement by firms.
  - Allocation of investor i, with relative risk aversion γ_i and climate preferences δ_i.

- The allocation decision is made by maximizing expected utility (Pástor, Stambaugh, and Taylor, 2021; Avramov et al., 2022):

$$U(w_i, \mathbf{x_i}) = -e^{-\gamma_i w_i - \frac{\delta_i}{\tau_B} \mathbf{x_i}' \boldsymbol{\tau}} \tag{3}$$

- The gross return of the portfolio depends on returns from the risk-free and risky assets :

$$w_i = (1 + r_f + \mathbf{x_i}' \mathbf{r})$$

w_i: gross return of the portfolio at $t = 1$
$\boldsymbol{\tau}$: vector of the decarbonization rates
$\mathbf{x_i} = (x_{i,1}, \cdots, x_{i,M})$: vector of portfolio weights
$\mathbf{r} = (r_1, \cdots, r_M)'$: vector of portfolio returns

Climate risk premium

- We assume that the return of an asset r_j has a CAPM + climate risk premium structure (Sharpe, 1964; Pástor, Stambaugh, and Taylor, 2021):

$$r_j = \beta_{mkt,j}\ r_{mkt} + \tilde{r}_j + \epsilon_j = r_{j,capm} + \tilde{r}_j + \epsilon_j \tag{4}$$

$$\tilde{r}_j = \begin{cases} (1-\lambda(1-\tau_B))\ \tilde{r}_B & \text{for type B companies} \\ (1-\lambda)\ \tilde{r}_H & \text{for type H companies} \\ \tilde{r}_N & \text{for type N companies} \end{cases}$$

$\beta_{mkt,j}$: sensitivity of asset j to the market return r_{mkt}
$\tilde{r}_j$: climate risk premium
$\epsilon_j \sim \mathcal{N}(0, \sigma_j^2)$ where σ_j^2 is the variance of j

Investor demand

After maximizing the expected utility of investor i, we have the following demand for type B, H and N stocks:

$$\mathbf{x_i} = \frac{1}{\gamma}\mathbf{\Sigma}^{-1}(\mathbf{r}_{capm} + \tilde{\mathbf{r}} + \frac{\delta_i}{\gamma\ \tau_B}\boldsymbol{\tau}) \tag{5}$$

$\mathbf{\Sigma}$: covariance matrix of stock returns.

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General market equilibrium

- The distribution of the stock market $\mathbf{s} = (s_B, s_H, s_N)$ and the investors' portfolio allocation provide a general market equilibrium:

$$\mathbf{s} = \frac{1}{\gamma}\ \boldsymbol{\Sigma}^{-1}\ (\tilde{\mathbf{r}} + \mathbf{r}_{capm} + \frac{\bar{\delta}}{\bar{\gamma}\ \tau_B}\boldsymbol{\tau}) \tag{6}$$

- A positive average demand from investors $\bar{\delta}$ reduces the climate risk premium for type B and type H firms.
- The general market equilibrium is very close in its form to Pástor, Stambaugh, and Taylor, 2021.
- We study the market equilibrium in 2 cases:
  - With 2 stocks in the economy, a type B and a type N.
  - With 3 stocks: a type B, a type H and a type N.

Economy with 2 stocks: type B and type N

- We first reduce the economy to two independent stocks: a type B and a type N, with:

$$s_B + s_N = 1 \quad \text{and} \quad \boldsymbol{\Sigma} = \text{diag}(\sigma_B^2, \sigma_N^2)$$

Assumption

All investors have an identical positive climate preference: $\delta > 0$ and a uniform risk aversion γ.

Assumption

Investors' portfolio allocation depends solely on diversifiable risk.

- Under these hypotheses, the market-clearing condition yields:

$$\mathbf{s} = \frac{1}{\gamma}\, \boldsymbol{\Sigma}^{-\mathbf{1}}\, (\tilde{\mathbf{r}} + \frac{\delta}{\gamma\ \tau_B}\boldsymbol{\tau}) \tag{7}$$

Economy with 2 stocks: strategies of firms and risk premia

Market equilibrium for each stock:

$$s_B = \frac{1}{\gamma\ \sigma_B^2}(1 - \lambda(1 - \tau_B))\ \tilde{r}_B + \frac{1}{\gamma\ \sigma_B^2}\ \frac{\delta}{\gamma}$$

$$s_N = 1 - s_B = \frac{1}{\gamma\ \sigma_N^2}\ \tilde{r}_N$$

In order to determine the supply and risk premia of each stock, we assume that the climate risk premium of the type B stock will be lower than the premium of the type N stock:

$$\tilde{r}_B = (1 - \tau_B)\ \tilde{r}_N$$

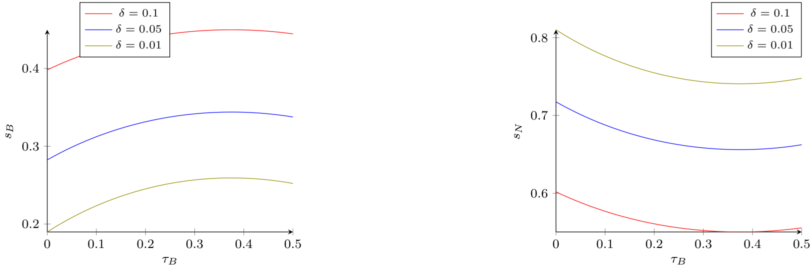
Economy with 2 stocks: supply of stocks

$$s_B = \frac{\frac{\sigma_B^2}{\sigma_N^2}\ (1-\lambda(1-\tau_B))\ (1-\tau_B) + \frac{\delta}{\sigma_B^2\ \gamma^2}}{1+\frac{\sigma_B^2}{\sigma_N^2}\ (1-\lambda(1-\tau_B))\ (1-\tau_B)} = 1 - s_N \quad (8)$$

Numerical application: $\gamma = 3$, $\sigma_B = \sigma_N = 0.2$, $\lambda = 0.8$

(a) Type B

(b) Type N



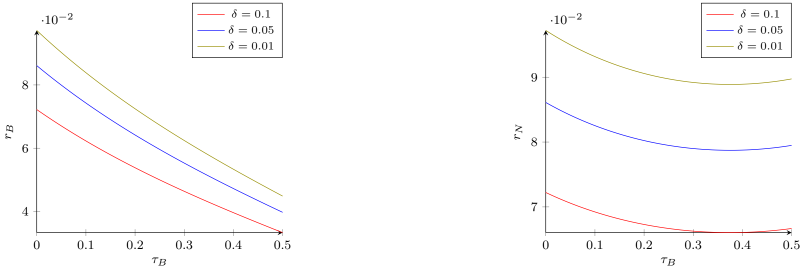
Number of type B and type N stocks in an economy with 2 companies.

Economy with 2 stocks: climate risk premium of stocks

- For the type B stock, the climate risk premium is the cost if the company fails to fulfill its target.
- For the type N stock, the climate risk premium serves as an incentive to attract investors.

(a) Type B

(b) Type N



Climate risk factor for type B and type N stocks in an economy with 2 companies.

Economy with 3 stocks: type B, H and N

- We extend our model by adding a company that has high abilities, with the following supply of stocks:

$$s_H = 1 - a^*$$
$$s_B + s_N = a^*$$

- Market-clearing conditions:

$$s_B = \frac{1}{\gamma\ \sigma_B^2}(1 - \lambda(1 - \tau_B))\ \tilde{r}_B + \frac{\delta}{\gamma^2\ \sigma_B^2}$$
$$s_H = 1 - a^* = \frac{1}{\gamma\ \sigma_H^2}(1 - \lambda)\ \tilde{r}_H + \frac{\delta}{\gamma^2\ \sigma_H^2}\ \frac{\tau_H}{\tau_B} \tag{9}$$
$$s_N = \frac{\tilde{r}_N}{\gamma\ \sigma_N^2}$$

- We keep the same assumption: $\tilde{r}_B = (1 - \tau_B)\ \tilde{r}_N$.

Economy with 3 stocks: supply of stocks

- Introducing a type H company in the model has an impact on the number of type N stocks.
- The climate preferences of investors are a determining factor in optimizing the number of stocks that commit to low-carbon targets.

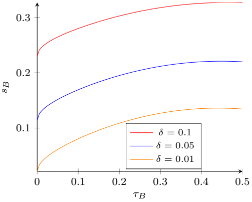
$$s_B = \frac{\frac{\sigma_B^2}{\sigma_N^2}\ a^*\ (1-\lambda(1-\tau_B))\ (1-\tau_B) + \frac{\delta}{\sigma_B^2\ \gamma^2}}{1+\frac{\sigma_B^2}{\sigma_N^2}\ (1-\lambda(1-\tau_B))\ (1-\tau_B)} \tag{10}$$

$$s_H = 1 - a^* \tag{11}$$

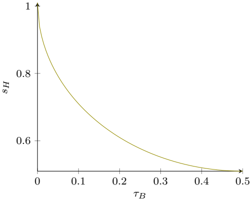
$$s_N = a^* - s_B = \frac{a^*\ -\ \frac{\delta}{\sigma_B^2\ \gamma^2}}{1+\frac{\sigma_B^2}{\sigma_N^2}\ (1-\lambda(1-\tau_B))\ (1-\tau_B)} \tag{12}$$

Economy with 3 stocks: supply of stocks

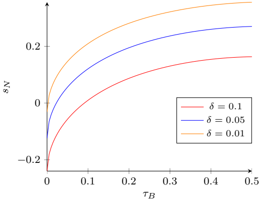
(a) Type B



(b) Type H



(c) Type N



Number of type B, type H and type N stocks in an economy with 3 companies.

Economy with 3 stocks: climate risk premium

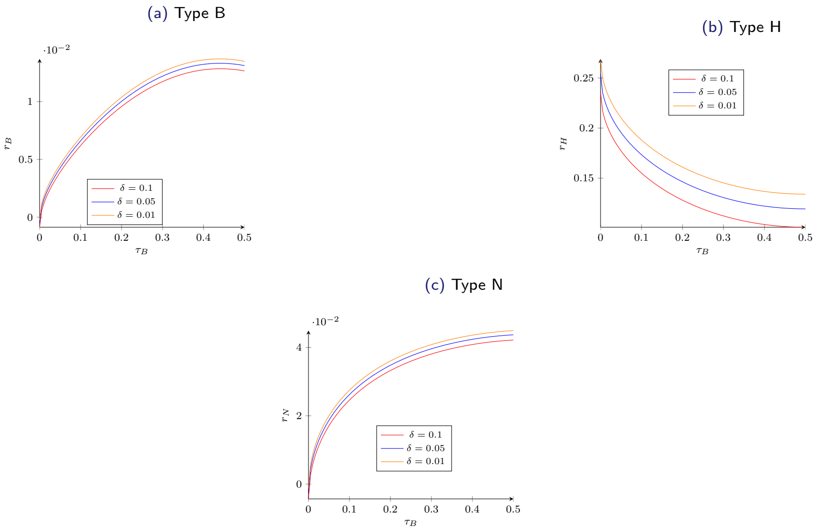
- The risk premium decreases when the company takes an ambitious target.
- The type N risk premium is an increasing function of τ_B: the company faces greater exposure to reputational and transition risk if there is climate urgency.

$$\tilde{r}_H = \frac{\gamma\ \sigma_H^2\ (1 - a^*) - \frac{\delta}{\gamma}\ \frac{\tau_H}{\tau_B}}{1 - \lambda} \tag{13}$$

$$\tilde{r}_N = \frac{\gamma\ \sigma_N^2\ a^*\ -\ \frac{\delta}{\gamma}}{1 + \frac{\sigma_B^2}{\sigma_N^2}\ (1 - \lambda(1 - \tau_B))\ (1 - \tau_B)} \tag{14}$$

$$\tilde{r}_B = (1 - \tau_B)\ \tilde{r}_N \tag{15}$$

Economy with 3 stocks: climate risk premium



Climate risk factor for type B, type H and type N stocks in an economy with 3 companies.

Portfolio decarbonization constraint

- Carbon budget constraint on the portfolio: the weighted-average portfolio emissions must be abated by level τ_B:

$$\sum_{j=1}^{M} x_{i,j}\ e_{j,1} = (1-\tau_B)\sum_{j=1}^{M} x_{i,j}\ e_{j,0}$$

- In a simplified form, efforts of type H stocks must compensate the lack of efforts from type N stocks.

- Under this constraint, unique climate preference:

$$\delta = \gamma^2\sigma_B^2\ (a^* + (1-a^*)\frac{e_{0,H}}{e_{0,N}}\ \frac{\tau_H-\tau_B}{1-\tau_B}\ (1+\frac{\sigma_B^2}{\sigma_N^2}\ (1-\lambda(1-\tau_B))\ (1-\tau_B))) \tag{16}$$

Empirical illustration: identifying a climate risk premium

- Impact of a low-carbon target announcement on stock returns: we expect a **negative effect** on the price of a stock after a company has **announced a low-carbon target**.

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- We test our hypothesis using a **difference-in-differences** on residual returns of stocks, controlling for market, size and value factors (returns are extracted from the Kenneth R. French library).
- Groups: returns from a stock with an SBTi target publication during a 130 business days before and after the publication (treatment), returns from a stock within the same industry without an SBTi target (control).

Empirical illustration: identifying a climate risk premium

Linear model for the difference-in-difference regression:

$$r_{res,i}(t) = \alpha_{i,p}\ d_p + \alpha_{i,g}\ d_g + \alpha_{i,pg}\ d_p\ d_g + \epsilon_i(t)$$

with d_p and d_g the dummy variables:

- $d_p = 0$ when $t <$ Publication Date and $d_p = 1$ when $t \geq$ Publication Date;
- $d_g = 0$ for the company that has not set any target, and $d_g = 0$ when the company has set a target.

Table: Identification of a climate risk premium.

Coefficients from the difference-in-difference regressions. The ‘Control Group’ column specifies the company which has not set a target. ‘α_p’ and ‘α_g’ are the coefficients from the time and group dummy variables. ‘α_{pg}’ give an indication of the existence of a climate premium. *, ** and ***: significant results at the 10%, 5% and 1% confidence intervals respectively.

Company	Control Group	Industry	Publication Date	Coefficients		
				α_p	α_g	α_{pg}
Electricite de France SA	Exelon Corporation	Utilities	10/12/2020	-0.00054	0.00434*	-0.01010**
Electricite de France SA	Pinnacle West Capital Corporation	Utilities	10/12/2020	-0.00139	0.00434*	-0.00925**
Electricite de France SA	Fortum Oyj	Utilities	10/12/2020	0.00024	0.00434*	-0.01088***
ENGIE	National Fuel Gas Company	Utilities	27/02/2020	0.00448*	0.00193	-0.01001**
ENGIE	Osaka Gas Co., Ltd.	Utilities	27/02/2020	0.00334	0.00193	-0.00887**
SSE	Fortum Oyj	Utilities	16/12/2021	-0.00593***	-0.00079	0.00736*
Continental AG	Goodyear Tire & Rubber Company	Automobile & Components	03/12/2020	0.00612*	0.00142	-0.00981*
Continental AG	Magna International Inc.	Automobile & Components	03/12/2020	0.00331	0.00142	-0.00700*
Air Liquide SA	Air Products and Chemicals, Inc.	Materials	19/05/2022	0.00132	0.00200	-0.00577**
Stora Enso Oyj Class R	Avery Dennison Corporation	Materials	21/10/2021	-0.00114	-0.00228	0.00587**
Stora Enso Oyj Class R	International Paper Company	Materials	21/10/2021	-0.00267	-0.00228	0.00740**
Stora Enso Oyj Class R	Packaging Corporation of America	Materials	21/10/2021	-0.00086	-0.00228	0.00559*
Stora Enso Oyj Class R	Sonoco Products Company	Materials	21/10/2021	-0.00166	-0.00228	0.00638**
Wheaton Precious Metals Corp	Sonoco Products Company	Materials	12/05/2022	0.00238	0.00100	-0.00732**
Wheaton Precious Metals Corp	Avery Dennison Corporation	Materials	12/05/2022	0.00261	0.00100	-0.00755**
ANA Holdings Inc.	Deutsche Lufthansa AG	Transportation	08/12/2022	0.00458**	0.00243	-0.00805**
Kuehne & Nagel International AG	Copa Holdings, S.A. Class A	Transportation	15/07/2021	0.00287	0.00199	-0.00597*
Kuehne & Nagel International AG	Old Dominion Freight Line, Inc.	Transportation	15/07/2021	0.00159	0.00199	-0.00469*
Kuehne & Nagel International AG	AerCap Holdings NV	Transportation	15/07/2021	0.00202	0.00199	-0.00511*
Norfolk Southern Corporation	Aurizon Holdings Ltd.	Transportation	29/07/2021	-0.00146	-0.00215	0.00452*

Agenda

Key takeaways and recommendations

- The ability of firms to abate their emissions is a determining factor for their strategy.
- Existence of non-monotonous solutions on alignment strategies: existence of a tipping point for optimizing the number of commitments.
- Investors should estimate the ability of firms to decarbonize and consider the credibility of transition plans.
- Benchmark pathways should remain below a tipping point, otherwise risking climate inaction from companies.
- Policies should take into account the appetance of investors for climate stocks as well as the risk profile of firms to orient investments.

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