



Carbon-Transition Risk

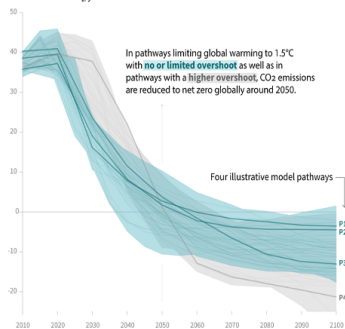
4th Frontiers of Factor Investing Conference

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What is carbon-transition risk?

Global total net CO₂ emissions

Billion tonnes of CO₂/yr



In pathways limiting global warming to 1.5°C with **no or limited overshoot** as well as in pathways with a higher overshoot, CO₂ emissions are reduced to net zero globally around 2050.

Four illustrative model pathways

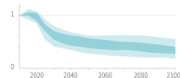
Timing of net zero CO₂
Line widths depict the 5-95th percentile and the 25-75th percentile of scenarios



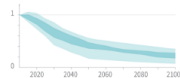
Non-CO₂ emissions relative to 2010

Emissions of non-CO₂ forcers are also reduced or limited in pathways limiting global warming to 1.5°C with **no or limited overshoot**, but they do not reach zero globally.

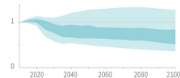
Methane emissions



Black carbon emissions



Nitrous oxide emissions



Source: IPCC Special Report on Global Warming of 1.5°C

- ▶ Global warming is at the forefront of policy and social debates.
- ▶ Decarbonization commitments.
- ▶ The stated objective is to reduce carbon emissions sufficiently to avoid an average temperature rise of more than 1.5 degrees Celsius by 2050.
- ▶ These commitments generate **transition risk** for corporations.
 - ▶ Uncertainty about the cost of transition.
 - ▶ Uncertainty about the evolution of investors' beliefs.

Drivers of transition risk

- ▶ Sources of transition risk
 - ▶ Technological (energy mix) changes
 - ▶ Political environment
 - ▶ Climate-related policy tightness
 - ▶ Investor/consumer pressure

Traditional approaches to measuring transition risk

- ▶ Use (hard data) firm-level emissions + decarbonization objectives as proxies for transition risk exposures (Bolton and Kacperczyk; JFE 2021, JF 2023).
- ▶ Use (soft data) of corporate communications as proxies for realized and expected transition risk (Sautner et al.; JF 2023).
- ▶ Potential shortcomings:
 - ▶ Measures based on past data.
 - ▶ Sources of risk not directly embedded in the risk measures.
 - ▶ No direct link to climate science.

Research context

- ▶ Link portfolio decisions to climate science through Net-Zero Portfolios (NZP).
- ▶ NZP mimic science-based decarbonization paths (Bolton, Kacperczyk, and Samama; FAJ 2022).
- ▶ NZP attracts a significant interest of investors.
 - ▶ Net-Zero Asset Managers Initiative: \$59 trillion pledged to carbon neutrality by asset managers
 - ▶ Net-Zero Asset Owners: \$10 trillion
 - ▶ Net-Zero Banking Alliance: \$67 trillion
 - ▶ Net-Zero Engagement Initiative (launched in March 2023)
- ▶ S&P has recently signed in the third largest client in its history (\$6 billion under NZP).

DTE: a new measure of transition risk

- ▶ **Integrate** transition risk within the framework of institutional NZ goals.
 - ▶ Transition risk reflects current and *expected* change in institutional pressure.
- ▶ Derive new measures of carbon transition risk: **distance-to-exit (DTE)**.
 - ▶ **Net-zero alignment:** measure the number of years firms have before they are excluded from NZP.
 - ▶ **Forward-looking metrics:** combine historical emission data with firms' emission reduction policy.
 - ▶ **Dynamic carbon budget:** carbon budget affected by changes in production of global emissions.

Institutional investors and transition risk: economic mechanism

- ▶ Institutional investors may affect transition risk of corporates
 - ▶ Divestment (Merton, 1987; Hong and Kacperczyk, 2009)
 - ▶ Engagement/voice (e.g., Krueger, Sautner, and Starks, 2020)
 - ▶ Active debate on the relative importance of these channels
- ▶ Innovation
 - ▶ Allow for a dynamic force of a portfolio divestment/engagement
 - ▶ Feedback effects between divestment and engagement + G.E. effects
 - ▶ Link climate asset pricing *directly* to climate science

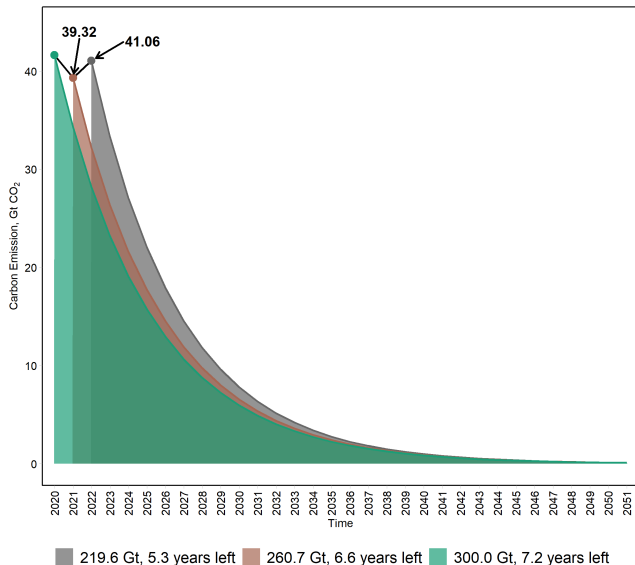
Carbon budget for net neutrality

- ▶ Intergovernmental Panel on Climate Change (IPCC) simulates global temperature changes under different emission paths.
- ▶ Our focus: limit global warming below **1.5°C** from pre-industrial levels with an **83%** probability.
- ▶ Implied carbon budget: emit maximum total of **260.7** GtCO₂ (as of beginning 2021).
- ▶ **39.3** GtCO₂ global emissions in 2020 (Global Carbon Project).
- ▶ Assuming **constant** emissions, remaining budget would be used up in **6.6 years** (260.7/39.3) .

Net-zero portfolios

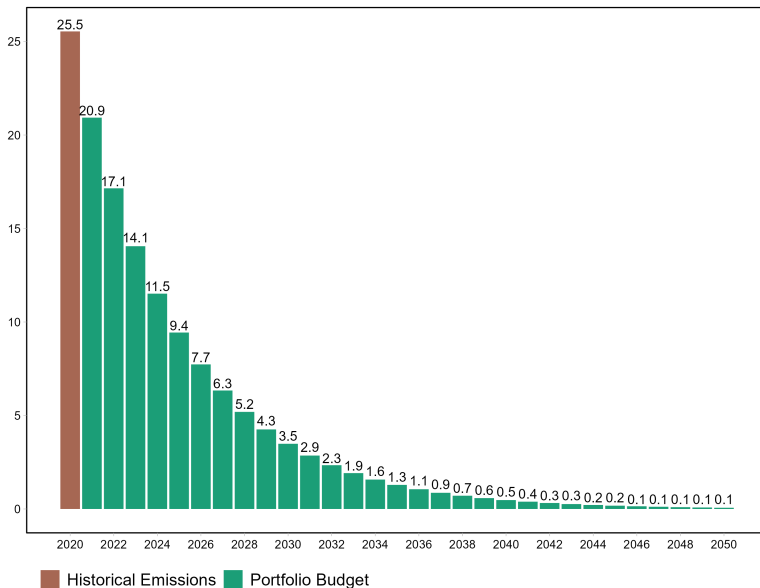
- ▶ Net-zero portfolios aim to align with the global decarbonization objectives.
 - ▶ NZAMI: “ambition to reach net zero emissions by 2050 or sooner across all assets under management.”
- ▶ Main steps to construct a net-zero portfolio:
 - 1 Define the investable stock universe (all Trucost stocks).
 - 2 Add up all firms' scope 1–3 emissions in a given year (25.5 GtCO₂ in 2020).
 - 3 Multiply the sum by the number of years left (**6.6 years** × 25.5 = 168.3 GtCO₂ beginning of 2021).
 - 4 Select companies so that total emissions cumulatively do not exceed the yearly emission budget.

Dynamic carbon budget for carbon neutrality: 2020-2022



- ▶ Global emissions **39.3** GtCO₂ in 2020.
- ▶ Global net-zero target:
 - ▶ Not to exceed the overall budget **260.7** GtCO₂ (from beginning of 2021).
 - ▶ Reduce global emissions to **zero** by 2050.
- ▶ Decarbonization from 2021 onwards implies:
 - ▶ Constant yearly **18.1%** emission reduction until 2050.
 - ▶ Emissions drop to **0.1** GtCO₂ in 2050.
 - ▶ Total emissions from 2021 to 2050 sum up to **178.0** GtCO₂ (within **260.7** budget limit).

Corresponding portfolio carbon budget 2021



Distance-to-exit (DTE) concept

- 1 **Budget**: set yearly carbon budget (of absolute emissions) at a *portfolio level* based on alignment path.
- 2 **Rank** companies by **the metric of decarbonization efforts** from worst to best, assuming *constant or estimated* future emissions.
- 3 **Exclude** first k companies until total emissions of remaining companies are within yearly carbon budget.
- 4 **Distance-to-exit (DTE)**: number of years a stock is not excluded from the portfolio. Exit year is assumed to be 2051 for companies that never get excluded.

Measuring decarbonization efforts: Ambition Score

▶ Novel forward-looking approach:

Ambition Score based on three categories:

1. Historical emissions data (50%): emissions levels and a 3-year moving average emission growth rate.
 2. Historical intensity data (25%): emissions intensity and a 3-year moving average intensity growth rate.
 3. Forward-looking data (25%):
 - ▶ Decarbonization policy, target information, and sustainability effort from CSR reports.
 - ▶ Green and brown patents data.
 - ▶ CDP targets and the level of target achievement.
 - ▶ SBTi commitment information.
 - ▶ Greenwashing indicator.
- ▶ Best-in-class: variables standardized within industry.
 - ▶ Simple average within category, then weighted average across categories.
 - ▶ Less aligned firms have higher score values.

Ambition Score: Apple Inc.

Category	Category Weight	Data Source	Variables	Reported Value	Score Input	Standardized Value
Historical hard data	50%	Trucost	Carbon emission	39,453,087.42	39,453,087.42	165.24
			Emission growth	0.14	0.14	0.68
Historical soft data	25%	Trucost	Carbon Intensity	143.72	143.72	-0.56
			Intensity growth	0.06	0.06	1.65
Forward-looking soft data	25%	CSR Report	Decarbonization target existence	Yes	0	-2.59
			Decarbonization policy existence	Yes	0	-1.75
			Emission disclosure	Reported	0	-1.94
			Sustainability committee existence	Yes	0	-2.08
			UNPRI signatory	No	1	NA
			SDG13 climate action	Yes	0	-2.63
		Orbis Patent	Green patent number	24	-24	-2.34
			Brown efficiency patent number	0	0	0.14
			Green patent citation number	264	-264	-16.1
			Brown efficiency patent citation number	0	0	0.11
			Green patent ratio	0.03	-0.03	0
			Brown efficiency patent ratio	0	0	0.08
		CDP Survey	SBTi participation	Submitted	1	-2.8
			Greenwashing indicator	0	0	3.18
			Abatement rate	5	-5	-6.35
Target underperformance	18.96		18.96	-3.83		
Target impracticability	18.00		18.00	-3.78		
					Final Score	40.93

Generalization: forecasted emissions

- ▶ **Issue:** future company emissions may change (organically or strategically), so assuming constant emissions may be too strong
- ▶ Forecast emissions based on:
 - (a) CDP commitments: aggregating targets with different ambitions and horizons at the firm level.
 - (b) Past emissions trends: use a 3-year moving-average emissions growth rate for 2 periods, then converge to an industry long-term growth rate until 2050.
- ▶ Weighted-average of (a) and (b) following the GFANZ target credibility framework.
 - 1 0% (a) + 100% (b): no long-term target (> 4 years).
 - 2 25% (a) + 75% (b): long-term target only but not SBTi validated.
 - 3 50% (a) + 50% (b): long-term and short-term target but not SBTi validated.
 - 4 50% (a) + 50% (b): long-term target only and SBTi validated.
 - 5 75% (a) + 25% (b): long-term and short-term target and SBTi validated.

Ranking by Ambition Score (2020)

Cumulative sum of constant emissions vs forecasted emissions

Company	Industry	Ambition Score	Rank	Emission	Cumulative Sum	DTE-ACE	Emission	Cumulative Sum	DTE-AFE
				Constant Carbon Emission at t			Forecasted Carbon Emission at t + 1		
GlycoNex Incorporation	Pharma	777.33	1	766.49	25,540,896,065.60	0	650.08	26,005,170,373.40	0
Berkshire Hathaway Inc.	Financials	331.78	2	96,466,704.66	25,540,895,299.11	0	85,585,349.93	26,005,169,723.32	0
Metro Pacific	Financials	229.36	3	4,742,804.79	25,444,428,594.45	0	4,977,899.08	25,919,584,373.40	0
...									
Apple Inc.	Technology	40.93	17	39,453,087.42	25,138,182,994.29	0	40,913,753.19	25,589,575,039.79	0
...									
Huaneng Power	Utilities	10.32	130	352,402,872.93	21,342,674,562.63	0	349,365,173.70	21,664,060,519.41	0
Nippon Steel Corporation	Materials	10.32	131	124,526,745.65	20,990,271,689.70	0	120,934,142.39	21,314,695,345.70	0
				Budget Cutoff 2021 20,928,993,022					
BP p.l.c.	Energy	10.29	132	124,243,014.60	20,865,744,944.05	1	119,973,019.20	21,193,761,203.31	0
Carnival Corporation	Consumer	10.22	133	6,910,616.46	20,741,501,929.46	1	6,917,054.10	21,073,788,184.11	0
...									
Foxconn Industrial Internet	Technology	9.16	150	9,365,871.44	20,630,847,717.94	1	9,457,379.12	20,965,103,171.73	0
PJSC Rosneft Oil Company	Energy	9.14	151	106,435,719.88	20,621,481,846.50	1	112,853,454.26	20,955,645,792.61	0
				Budget Cutoff 2021 20,928,993,022					
Shandong Xinhua	Pharma	9.09	152	465,566.20	20,515,046,126.62	1	509,591.40	20,842,792,338.35	1
Aluminum Corp China	Materials	9.03	153	94,350,394.24	20,514,580,560.43	1	107,911,951.65	20,842,282,746.95	1
...									
Bupa Arabia	Insurance	-3.80	14082	78,252.12	78,252.12	30	57,745.46	57,745.46	30

DTE of Apple: time series

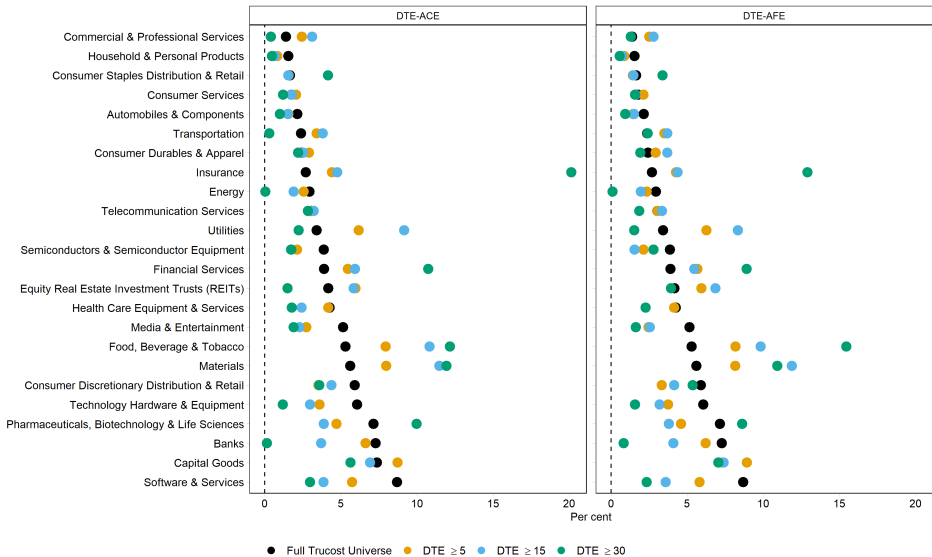
Estimation Year		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Ambition Score	Percentile Ranks	20.69	28.26	29.18	25.39	13.71	4.06	2.45	2.77	1.99	1.26	1.65	0.26	0.14	0.11	0.12	0.10
DTE-ACE	Exit Year	2014	2016	2017	2017	2015	2013	2014	2015	2016	2016	2017	2018	2019	2020	2021	2022
	Distance-to Exit	7	8	8	7	4	1	1	1	1	0	0	0	0	0	0	0
DTE-AFE	Exit Year	2012	2013	2015	2016	2015	2013	2013	2015	2016	2016	2017	2018	2019	2020	2021	2022
	Distance-to Exit	5	5	6	6	4	1	0	1	1	0	0	0	0	0	0	0

- The ambition-based DTE changes over time due to a changing **budget** and ambition score **ranking**.

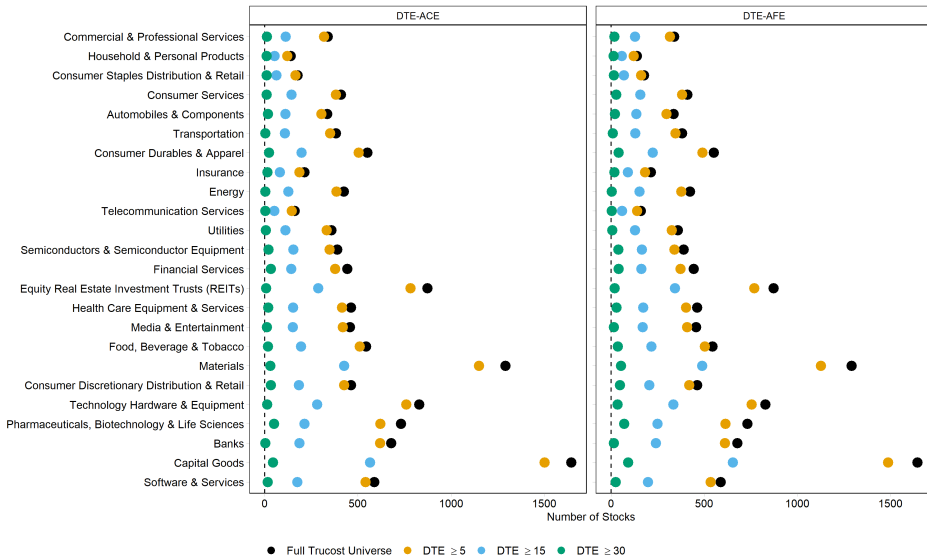
Data sources

- ▶ Primary database combines several datasets.
 - ▶ Firm-level corporate carbon and other greenhouse gas emissions globally from Trucost.
 - ▶ Disclosures from Corporate Social Responsibility reports via Refinitiv.
 - ▶ Commitments collected from CDP.
 - ▶ Patents from Orbis IP Financial.
 - ▶ Stock returns and corporate fundamentals from Compustat.
- ▶ 14,693 unique publicly listed companies (about 90% of total market cap) representing 104 countries and spanning all industries over the period 2006-2021.

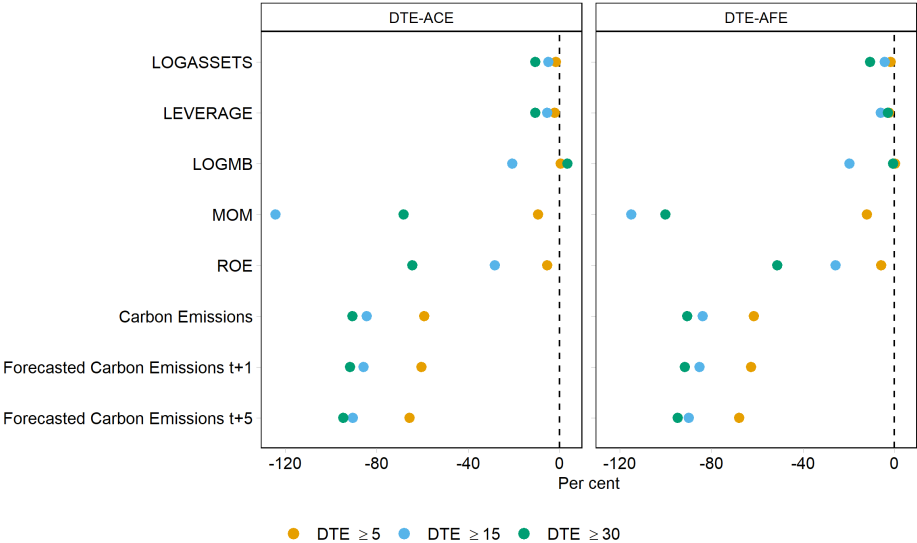
Anatomy of DTEs: industry exposure (2020)



Anatomy of DTEs: number of DTE-investable stocks (2020)



Anatomy of DTEs: DTE-investable stock characteristics (2020)



Transition risk and stock returns/valuations

- ▶ Estimate a pooled regression model (a la Daniel and Titman, 1998):
 - ▶ Monthly future stock returns and PE ratios as dependent variables.
 - ▶ DTE as a main explanatory variable (observed on an annual basis).
 - ▶ Various firm-level characteristics as controls.
 - ▶ Include year-month, industry, and country fixed effects.
 - ▶ Double cluster standard errors at firm and year dimensions.
 - ▶ Coefficient of DTE identifies average carbon transition risk premium.

Basic results

Dependent variable:	Returns		Controlling for Ambition Score		LOGPE	
	(1)	(2)	(3)	(4)	(5)	(6)
DTE-ACE	-0.028*** (0.006)		-0.028*** (0.006)		0.006*** (0.001)	
DTE-AFE		-0.025*** (0.006)		-0.025*** (0.006)		0.005*** (0.001)
Ambition Score			-0.087 (0.112)	-0.067 (0.111)		
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year-month-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	922,365	922,365	922,365	922,365	579,357	579,357
R-squared	0.120	0.120	0.120	0.120	0.229	0.228

Economic significance: 2.5-4.6% annualized return difference per one st. dev. of DTE.

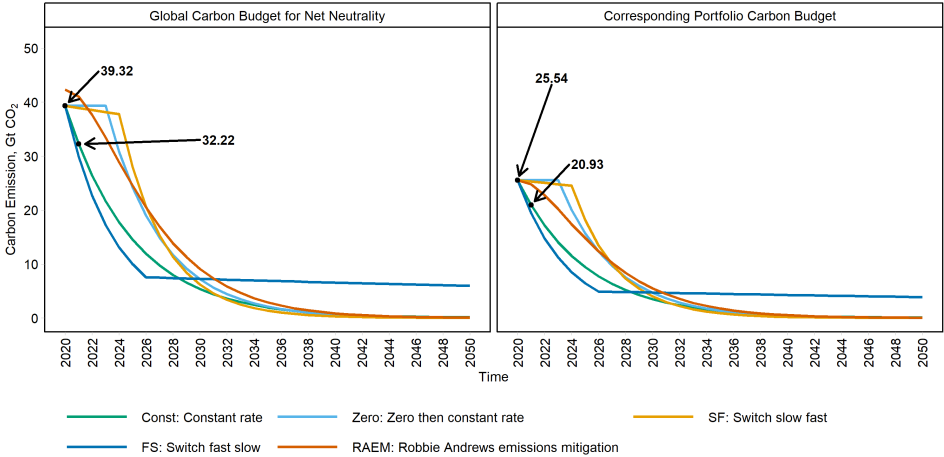
Robustness tests

- ▶ Explore additional tests to check the robustness of our results.
 - ▶ Changes in investors' perception (Paris Agreement).
 - ▶ Alternative decarbonization pathways.
 - ▶ Extensive margin.
 - ▶ Scope 1 and 2 emissions.

The effect of Paris agreement

Dependent variable: RET	Returns		LOGPE	
	(1)	(2)	(3)	(4)
DTE-ACE	-0.017** (0.006)		0.005*** (0.001)	
DTE-ACE × Paris	-0.018* (0.010)		0.001 (0.002)	
DTE-AFE		-0.015** (0.005)		0.004*** (0.001)
DTE-AFE × Paris		-0.018* (0.010)		0.001 (0.001)
Controls	Yes	Yes	Yes	Yes
Country-fixed effects	Yes	Yes	Yes	Yes
Industry-fixed effects	Yes	Yes	Yes	Yes
Year-month-fixed effects	Yes	Yes	Yes	Yes
Observations	922,365	922,365	579,357	579,357
R-squared	0.120	0.120	0.229	0.229

Alternative decarbonization pathways



Alternative decarbonization pathways: results

	Dependent Variable: RET.		Dependent Variable: LOGPE.	
	Pathway: RAEM	Pathway: RAEM	Pathway: RAEM	Pathway: RAEM
	(1)	(2)	(3)	(4)
DTE-ACE	-0.025*** (0.006)		0.006*** (0.001)	
DTE-AFE		-0.020*** (0.006)		0.005*** (0.001)
Observations	922,365	922,365	579,357	579,357
R-squared	0.120	0.120	0.229	0.229
Controls	Yes	Yes	Yes	Yes
Country-fixed effects	Yes	Yes	Yes	Yes
Industry-fixed effects	Yes	Yes	Yes	Yes
Year-month-fixed effects	Yes	Yes	Yes	Yes

Extensive margin

Dependent variable:	Returns	
	(1)	(2)
EXT DTE-ACE	-0.216 (0.154)	
EXT DTE-AFE		-0.261*** (0.078)
Controls	Yes	Yes
Country-fixed effects	Yes	Yes
Industry-fixed effects	Yes	Yes
Year-month-fixed effects	Yes	Yes
Observations	963,697	963,697
R-squared	0.121	0.121

Returns and DTEs: scope 1 and 2

Dependent variable:	Returns	
	(1)	(2)
DTE-ACE	-0.014*** (0.004)	
DTE-AFE		-0.013*** (0.004)
Controls	Yes	Yes
Country-fixed effects	Yes	Yes
Industry-fixed effects	Yes	Yes
Year-month-fixed effects	Yes	Yes
Observations	922,365	922,365
R-squared	0.120	0.120

Conclusions

- ▶ Transition risk is an important factor in setting incentives to decarbonize.
- ▶ Distance-to-exit framework links transition risk and the pressure from institutional investors.
- ▶ The growing importance of NZ portfolios will likely amplify the economic significance of the effect on asset prices.