Climate Impact Investing Is Coming On Fast…

What Portfolio Managers Need to Know — and Do — to Successfully Adapt

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There is no denying the impact of climate change — and associated regulatory realities — on the business of investment management. For portfolio managers, it is essential to understand how to successfully adapt and prepare for what some call the "mother of all correlated risks"[1]. Here we expose — in three parts — what portfolio managers need to know when switching to a fully Paris Aligned Benchmark (PAB) portfolio from a current market-cap weighted (CWB) portfolio.

We start by putting both portfolios through a battery of historical and transitive stress tests representing past and current world events to see how each one performs under these scenarios. Our goal here is to identify what, if any, specific tail events may come with the decision to adopt a climate-aligned portfolio. In other words, in doing the right thing for the environment today, are we exposing ourselves to possible downside risk costs tomorrow, as indicated by the rebalancing from the point of view of changes in sector allocations and style factor exposures?

"Climate impact investing is not a fad, it is a regulatory reality hurtling towards non-compliant portfolios… and it represents a thematic risk premium that investors can harvest between now and when regulations come into effect."

Next, we look at the differences in the sensitivities of these portfolios to a wide variety of single risk and macro factors. Finally, we examine the possible market impact costs of having many portfolio managers rebalance away from the cap-weighted benchmark to the Paris Aligned ones in an undisciplined manner (a.k.a. at the last regulatory minute and all together).

To facilitate investor decision making with regard to building Paris Accord Climate-compliant portfolios, STOXX released in July 2020 a family of Climate indices: the STOXX Paris-Aligned Benchmark (PAB) Indices and the STOXX Climate Transition Benchmark (CTB) Indices. The new PAB Benchmarks track the performance of liquid securities from a selection of underlying cap-weighted STOXX Benchmark indices. They comply with, and exceed, the PAB requirements as laid out by the European Commission's Technical Expert Group (TEG) Final Report, and is designed to guarantee the alignment with a 1.5 degree trajectory[2]. In this note, we will be contrasting the parent cap-weighted index portfolio with its climate-aligned variant PAB indices. The analysis focuses on the US versions of the PAB and cap-weighted portfolios, and uses the benchmark constituent weights as of September 30, 2020.

This paper is arranged as follows. In **Section 1** we use Axioma Portfolio Optimizer™ to compare and contrast the two variants (i.e., CWB & PAB) of the STOXX USA 900[3] in terms of risk characteristics, using the Axioma US Fundamental Equity Factor Risk Model - Medium-Horizon (AXUS4-MH), Global Industry Classification Standard (GICS) Sector allocations, and Style factor exposures. Our goal here is to obtain a high-level decomposition of the current active risk between the two variants.

[1] See Erik Gerding, Professor & Wolf-Nichol Fellow, Colorado Law, University of Colorado, Boulder: "Money Stuff: Catastrophes and Correlations," Bloomberg, February 10, 2020
[2] Report accessible here
[3] This analysis was conducted on the STOXX USA 900, STOXX Europe 600, and STOXX Global 1800 and their respective climate variants (CTB and PAB). This paper discusses the results for the STOXX USA 900 family; the tables for the other two regional indices are available upon request.

In **Section 2**, we use Axioma Risk™ to put both the parent and the STOXX® USA 900 PAB benchmark through a battery of stress tests, both historical and transitive, shocking both pricing and risk factors in turn, and using historical market events and modeling geopolitical events that may or may not happen. Our goal here is to identify scenarios with material differences in the expected gain/loss to our benchmark portfolios from being climate compliant (i.e., are there downside risk costs to adopting the PAB portfolio today).

In **Section 3**, we simulate an orderly rebalancing from the CWB to the PAB for varying levels of AUM and trading constraints set in terms of % of Average Daily Volume (ADV) for the trades in question. Our goal here is to find out how many days it would take portfolio managers to rebalance their portfolios for different levels of AUM and by varying the percent-of-ADV constraint.

Finally, in **Section 4**, we simulate a scenario where large amounts of AUM (USD 5bn, USD 10bn, USD 50bn, USD 100bn, and USD 200bn) are rebalanced from the CWB to the PAB simultaneously, while measuring the market impact they would incur by executing these trades in a single day. Our goal here is to stress test the entire market and quantify the market impact of waiting until the last minute to switch from CWB to the PAB[4].

Section 1 – Relative Risk and Exposure Analysis as of September 30, 2020

We begin by looking at the relative risk of the PAB variant to its cap-weighted parent, to get a sense of the active risk incurred as of now to be climate-compliant. We note that the active risk is roughly on par with the average active risk of fundamental portfolio managers with developed market mandates (i.e., about 2-3%). This means that becoming climate-aware today *is* an active strategy in itself and a manager adopting either the climate portfolio, while still being benchmarked against a cap-weighted index, needs to have a commensurate expected return forecast from his or her active climate bets.

One could argue, especially in Europe, that this return forecast is a sort of *'climate transition active risk premium'* and that as institutional investors are gradually mandated to adopt climate impact investing rules, harvesting this premium can be achieved by adopting a PAB benchmark ahead of time. A naïve model assuming a) normally distributed active returns; b) a 2.47% Active risk between the PAB and CWB portfolios (from Figure 1); and c) a requirement for a 68% confidence (2 out of 3 times) of beating the CWB return, would put that *'climate transition active risk premium'* at 1.15%.

Figure 1 on the next page shows the active risk decomposition for the PAB variant against the cap-weighted parent index.

[4] To be fair, if a manager waits until the last (regulatory) minute, chances are the cap-weighted benchmark will already resemble the PAB benchmark in terms of sector allocations, given that most investors will have gradually sold companies on the exclusion list and bought those on the inclusion list. So, this market impact analysis refers to the cost of switching today rather than in five, 10, or 15 years from September 30, 2020.

Figure 1 – Active Risk Decomposition as of September 30, 2020

STOXX USA 900 PAB Active Risk Decomposition	Active Risk (SD)	% of Active Risk
Total Active Risk	2.5	100
Specific Active Risk	1.4	31.5
Factor Active Risk	2.0	68.5
US4AxiomaMH.Style	1.3	36.9
US4AxiomaMH.Industry	1.2	31.6
US4AxiomaMH.Market	0.0	0.0

Source: Axioma Portfolio Optimizer

We note that while the inclusion rules used in the construction of these indices are almost exclusively based on industry classification (i.e., the type of business model and its reliance on activities that generate carbon emissions), the contribution to total active risk from Style factor exposures is larger than the contribution from industry factor exposures[5].

Figure 2 shows the active style risk decomposition ranked by the volatility of the style factors. The exposures show that the PAB variant has a slight tilt towards companies that are more positively sensitive to exchange-rate movements, are more profitable, have a higher Earnings Yield (i.e., lower PER), have larger market caps, and are more growth oriented than the parent index. Conversely, PAB constituents on average tend to be less liquid, have lower betas (to market risk), less debt, are less volatile, have negative active exposures to Value and Momentum (the latter being the most likely to change over time), and pay a lower dividend than those of the parent index.

As of the analysis date (September 30, 2020), the PAB's negative active exposure to the Market Sensitivity and Volatility factors, as well as its positive active exposure to Size and Profitability, drove most of the active style factor risk for that portfolio, given the volatility of those factors.

[5] This holds true for all three regions on that date, as some of the technical factors (Size, Market Sensitivity, and Momentum in particular) were quite volatile.

Figure 2 – Active Style Risk Decomposition as of September 30, 2020

STOXX USA 900 PAB Active Style Risk Decomposition	Factor Volatility	Active Exposure	% of Active Risk
Sub-Total Style Factors	N/A	N/A	36.9
Size	9.6	0.0465	6.5
Market Sensitivity	9.2	-0.0588	13.3
Medium-Term Momentum	8.5	-0.0106	-0.7
Volatility	7.7	-0.0502	5.5
Value	4.5	-0.0186	1.2
Profitability	4.4	0.0746	4.0
Earnings Yield	4.0	0.0497	-1.6
Liquidity	3.3	-0.0703	3.0
Exchange Rate Sensitivity	3.1	0.0764	2.8
Growth	2.9	0.0171	-0.2
MidCap	2.6	-0.0476	0.7
Dividend Yield	2.6	-0.0048	0.1
Leverage	2.3	-0.0515	2.1

Source: Axioma Portfolio Optimizer

The other big contributor (31.6%) to active risk comes from the industry factors and the different allocations the PAB portfolio has to each one versus the parent index. Figure 3 on the next page shows the allocation and contribution to total portfolio active risk from the industry factors grouped by GICS sectors for both the portfolios.

We note that the Energy sector, in its current form[6], is completely absent from the PAB portfolios. Health Care, Information Technology, and Consumer Staples get the biggest *increases* in weights, while Industrials, Utilities, Energy, and Consumer Discretionary get the biggest *decreases* in absolute terms. These are meaningful sector differences and require care and patience to execute as portfolio managers shift from one benchmark to the other in their effort to become climate-regulation compliant (see Section 3).

[6] Note that it is possible, probably even likely, that some of Energy companies reinvent themselves as 'green' energy producers over time and are restored to the index in the future.

Figure 3 – Active Sector Allocation and % of Active Risk as of September 30, 2020

Sector Weights / Active Weights	STOXX USA 900	STOXX USA 900 PAB	PAB ACTIVE WEIGHT	% of ACTIVE RISK
Communication Services	8.9%	8.7%	-0.2%	1.2%
Consumer Discretionary	12.8%	11.3%	-1.4%	4.2%
Consumer Staples	6.6%	9.5%	2.9%	2.0%
Energy	1.9%	0.0%	-1.9%	6.6%
Financials	9.1%	8.5%	-0.6%	0.5%
Health Care	14.4%	20.9%	6.5%	-1.8%
Industrials	8.8%	2.9%	-5.9%	13.4%
Information Technology	29.2%	32.7%	3.5%	0.2%
Materials	2.3%	2.3%	0.1%	0.2%
Real Estate	3.1%	2.5%	-0.6%	1.5%
Utilities	2.9%	0.5%	-2.4%	3.5%

Source: Axioma Portfolio Optimizer

The negative active weight of -5.9% in Industrials is the biggest contributor to Active Risk (13.4%), followed by the exclusion[7] of the Energy sector (6.6%), the -1.4% active weight in Consumer Discretionary (4.2%), and the -2.4% active weight in Utilities (3.5%). Conversely, the 6.5% overweight in Health Care helps to reduce total active risk by -1.8% and is the only active risk-reducing sector exposure in the PAB index[8].

We also note that Facebook, Amazon, Apple, Netflix, Google (the 'FAANGs') + Microsoft, which accounted for 19.7% of the parent index's weight and 18% of its risk on September 30, 2020, have a smaller weight of 16.5% in the PAB portfolio and contribute only 16% to its risk, meaning that the influence of Big Tech would actually be slightly reduced by a move to climate compliance[9]. A reduced concentration risk could come in handy if the Biden administration goes after Big Tech, either through its fiscal policy or via increased regulatory oversight (see FAANG + M stress test in Section 2).

In conclusion for this section, the decision to switch from a cap-weighted benchmark to a climate-compliant one today comes with considerable active risk in the form of both style and sector exposures, and would require an additional active risk premium to justify without a corresponding change in benchmark. In the next section, we investigate additional downside risks these active style and sector exposures could bring.

[7] As per PAB rules: (i) exclusion of companies that have more than either 1% of revenues from coal, 10% from fossil fuels and 50% from natural gas (ii) keeping the overall exposure to eight GHG-intensive sectors constant, this constraint is applied using NACE code, explaining why Energy might not appear in the table using GICS Sectors.
[8] Based on the covariance matrix as of that date.
[9] The ICT sector is said to produce more GHG than plane travel (above 4% of global GHG), which explains the industry's reduced weight in the PAB design. This seems to be debated, though, and needs verification.

Section 2 – Stress Testing and Sensitivity Analysis as of September 30, 2020

In this section we put both the STOXX USA 900 (CWB) and the STOXX USA 900 PAB (PAB) portfolio as of September 30, 2020 through a series of geopolitical stress tests and single factor shocks. Our goal is to identify market conditions that could yield a significant difference in outcomes for our two benchmark variants. In other words, we want to know if doing right by the environment comes with any unexpected downside risks to which we would otherwise not be exposed with a cap-weighted benchmark.

Figure 4 – Stress Testing Scenarios, Expected Returns

THEME	STRESS TEST NAME	STRESS TEST TYPE	DESCRIPTION	STOXX USA 900	STOXX USA 900 PAB
PANDEMIC HISTORY	SARS Q4 2002	Historical	Oct 01 - Dec 31, 2002	5.4	4.9
	SARS Jan 2003	Historical	Jan 01 - Jan 31, 2003	-5.5	-5.3
	SARS Jan-Mar 2003	Historical	Jan 01 - Mar 12, 2003	-10.8	-10.3
	SARS Q2-2003	Historical	Apr 01 - Jun 30, 2003	15.7	14.2
	COVID-19 CRASH	Historical	Feb 20 - Mar 23, 2020	-33.4	-31.2
	COVID-19 REBOUND	Historical	Mar 24 - Jun 08, 2020	47.2	44.2
US ELECTIONS	9/11	Historical	Sep 17 - Sep 21, 2001	-8.2	-8.9
	Obama Reelection	Historical	Nov 01 2012 - Jan 31, 2013	7.5	8.6
	Trump Surprise Win	Historical	Nov 01 2016 - Jan 31, 2017	9.7	9.1
	BP/RS	Transitive	SPX +10%, DXY +20%,USTB 10Y +20bps	10.3	9.9
	BP/DS	Transitive	SPX -10%, DXY -10%,USTB 10Y +20bps	-12.2	-11.9
	TP/RS	Transitive	SPX +10%, DXY +10%,USTB 10Y +20bps	10.8	10.7
	TP/DS	Transitive	SPX -10%, DXY -10%,USTB 10Y -20bps	-9.5	-9.7
BIG TECH	FAANG + M + T	Transitive (3M)	FAANG + MS + Telsa down 20%	-9.9	-9.9
SECTOR SHOCKS (SPDR SECTOR ETFs)	Comm Servcs	Transitive (3M)	SPDR Comm Servcs -20%	-1.1	-1.0
	Cons Disc	Transitive (3M)	SPDR Cons Disc -20%	-4.0	-3.9
	Cons Staple	Transitive (3M)	SPDR Cons Staple -20%	-0.1	-0.7
	Energy	Transitive (3M)	SPDR Energy -20%	-0.4	0.0
	Financials	Transitive (3M)	SPDR Financials -20%	-1.3	-1.2
	Health Care	Transitive (3M)	SPDR Health Care -20%	-5.0	-6.3
	Industrials	Transitive (3M)	SPDR Industrials -20%	0.0	0.7
	Info Tech	Transitive (3M)	SPDR Info Tech -20%	-5.1	-4.9
	Materials	Transitive (3M)	SPDR Materials -20%	-1.2	-1.3
	Real Estate	Transitive (3M)	SPDR Real Estate -20%	-0.9	-0.8
	Utilities	Transitive (3M)	SPDR Utilities -20%	-0.4	-0.2

Based on holdings on September 30, 2020

Source: Axioma Risk

Figure 4 shows the results of 25 different stress tests, covering a wide range of geopolitical and macro themes, such as the COVID-19 pandemic, the US Presidential elections, increased regulatory oversight and taxing of Big Tech, as well as individual sector shocks—all of which have been the subject of blog posts by the Applied Research team at Qontigo in the last 12 months. The values represent the expected returns for the portfolios.

The highlighted rows represent scenarios where the expected loss/gain for the PAB portfolio clearly differed from the CWB portfolio — orange for worse, green for better. Only seven of the 25 scenarios produced a meaningful difference in the expected impact to the portfolio, and in only four was that difference material (where material is defined as greater than our naïve *'climate transition active risk premium'* of 1.15%). Of those four, one was the 20% shock to the Health Care sector, which is not surprising given the PAB's overweight in that sector. The other three involved historical pandemic scenarios, where the PAB portfolio would be expected to underperform during the post-pandemic rebound, due to its slightly defensive style factor exposures and the underweight in cyclical sectors, such as Industrials, Consumer Discretionary, and Energy. Overall, across all 25 stress test scenarios, the average difference in expected outcomes was a negligible 0.1%.

The PAB portfolios were designed to help investors reduce climate transition risk (i.e., minimize exposure to carbon-intensive business models that would prevent economies/countries from reaching their Paris Accord emission targets). In this section, we conducted a series of physical risk stress tests on both portfolios to identify if a PAB portfolio of companies that do better than their peers in terms of greenhouse-gas emissions intensity are more or less likely to be impacted by extreme weather events. We replayed the history of past mega-hurricanes, heatwaves, floods, a major oil spill, and an additional industry factor shock to the Insurance industry[10], to find out how each of our current portfolios would have performed during those extreme weather-related events.

Figure 5 shows the results in terms of percent expected change in the portfolio's net present value from these events. None of the extreme weather scenarios resulted in a difference in expected gain/loss for the portfolios that was greater than our naïve *'climate transition active risk premium'* target of 1.15%. The average difference between the two portfolios across all eight scenarios was just 0.1%. The worst outcome was from the Deepwater Horizon oil spill (a.k.a. the BP Oil Spill) where the PAB portfolio would have suffered a 0.95% greater loss than the CWB portfolio. The best outcome was during the EU Floods of 2018, where the PAB portfolio would have outperformed its CWB counterpart by +0.63%[11].

[10] Interestingly, insurance stocks benefit from weather disasters, as analysts upgrade their forecasts for the following year, based on the practice of raising premiums and increased demand for insurance post-disaster from customers who lacked coverage before.

[11] The STOXX Europe 600 PAB—its European counterpart—would have outperformed the parent index by as much as 0.96% during this extreme weather event.

Figure 5 – Extreme Weather Scenarios Expected Returns

Historical Event	STOXX USA 900	STOXX USA 900 PAB	DELTA
Hurricane Katrina - 08/29 2005	0.37	0.43	0.06
Hurricane Sandy - 10/30 2012	1.10	1.01	-0.09
Hurricane Harvey - 08/27 2017	1.82	1.97	0.15
Hurricane Irma - 09/10 2017	1.90	2.22	0.32
SPDR Insurance -20%	-8.92	-8.44	0.49
Deepwater Horizon - 04/20 2010	-7.87	-8.82	-0.95
EU Heatwave - 06/07 2019	1.77	2.00	0.22
EU Floods - 10/11 2018	-3.57	-2.94	0.63

Based on holdings on September 30, 2020
Source: Axioma Risk

Figure 6 takes a closer look at the Deepwater Horizon oil spill, showing the contribution to total portfolio expected loss from each sector exposure. We see that most of the underperformance of the PAB portfolio is expected to come from its over-weights in Health Care and in Information Technology. On the other hand, its under-weight in Industrials and Energy would have benefited the PAB portfolio and helped to minimize losses from this event.

Figure 6 – Sector Contribution to Total Portfolio Expected Loss – Deepwater Horizon

DEEPWATER HORIZON - SECTOR CONTRIBUTIONS	STOXX USA 900	STOXX USA 900 PAB	DELTA
PORTFOLIO TOTAL	-7.87	-8.82	-0.95
Communication Services	-0.39	-0.53	-0.14
Consumer Discretionary	-1.10	-0.97	0.13
Consumer Staples	-0.35	-0.45	-0.10
Energy	-0.20	0.00	0.20
Financials	-1.10	-1.09	0.01
Health Care	-1.18	-1.83	-0.65
Industrials	-0.63	-0.16	0.47
Information Technology	-2.53	-3.48	-0.95
Materials	-0.15	-0.15	0.00
Real Estate	-0.10	-0.12	-0.02
Utilities	-0.12	-0.03	0.09

Source: Axioma Risk

Next, we set up a series of 17 single factor shocks to measure the sensitivities of our two portfolios to each individual factors. The range of factors selected for this analysis includes market factors, style factors, commodities, interest rates, inflation, and credit spreads. The goal here is to identify specific risk factors to which a climate portfolio would be overly sensitive, vis-à-vis its cap-weighted counterpart (i.e., does being climate-compliant come with individual sensitivities of which we are unaware).

In this report, we simply regress the time series of each individual factor (price time series for indices, factor returns for style factors), against the factor returns time series, then scale those results to the factor exposures of our portfolios and report the sensitivity of our two portfolios as betas to these factors. So, for example, a beta of 0.93 for the PAB portfolio on the US Equities shock means that the STOXX USA 900 PAB portfolio's beta to the S&P 500 return is 0.93 (i.e. it would move by almost the same amount and in the same direction since the two are positively correlated). The sign of the beta reflects the correlation of the portfolio to the factor time series. In this report, the correlation is calibrated using daily data for the past three months (i.e. these are the sensitivities we would have to deal with in the short term).

Figure 7 shows the results of our sensitivity analysis. The average difference between the two portfolios across all 17 sensitivity tests is about zero (0.03). The PAB portfolio was moderately more sensitive to only four factors and less sensitive to one: Leverage (more sensitive by 0.28), Volatility (less sensitive by 0.21), Exchange Rate Sensitivity (more sensitive by 0.21), Growth (more sensitive by 0.18), and Short-Term Momentum (more sensitive by 0.13). Recall that these betas are estimated using the prior three months of daily data and therefore represent current betas rather than longer-term averages. The same analysis can be run using five years of monthly data to establish more longer-term differences[12].

[12] For example, the beta of the PAB to the Leverage factor in the AXUS4-MH model using five years of monthly data is 1.1 versus 1.2 for the cap-weighted parent index (i.e. virtually the same).

Figure 7 – Factor Sensitivities – As of September 30, 2020

SENSITIVITY ANALYSIS	DESCRIPTION	STOXX USA 900	STOXX USA 900 PAB	DELTA
US Equities	S&P500 Index	0.95	0.93	-0.02
Global Market	Global Market Factor	1.24	1.21	-0.03
Exchange Rate Sensitivity	ERS Factor	0.13	0.34	0.21
Value	Value Factor	0.00	0.00	0.00
Growth	Growth factor	1.54	1.72	0.18
Medium-term Momentum	MTM Factor	1.37	1.45	0.08
Short-term Momentum	STM Factor	0.26	0.39	0.13
Liquidity	Liquidity Factor	1.02	1.01	-0.01
Volatility	Volatility Factor	1.00	0.79	-0.21
Size	Size Factor	1.02	1.03	0.01
Leverage	Leverage Factor	2.02	2.30	0.28
DXY	Dollar Index	-0.80	-0.76	0.03
Oil	Oil Prices	0.27	0.26	-0.02
GSCI Commodity Index	GSCI Index	0.45	0.42	-0.03
US Long Rate (30Y)	BBG Barclays US Treasuries: 25+ YR	-0.20	-0.18	0.02
US Inflation Rate (5Y)	BBG Barclays US TB Inflation Notes 1-10Y	2.69	2.59	-0.10
US SUBIG Credit Spread (5Y)	BBG Barclays US Corporate HY	1.58	1.52	-0.06

Source: Axioma Risk

In conclusion to this section, we determined that doing right by the environment should not materially impair portfolio performance. None of the stress tests or sensitivity analyses we put our PAB portfolio through resulted in unacceptable increases in downside risk or sensitivities versus the CWB portfolio. For those scenarios that were negative for the CWB, they were less negative for the PAB portfolio. For those that were positive, they were slightly less positive for the PAB portfolio. The differences were in line with the exposure differences between the two portfolios and confirmed the PAB's more conservative personality (i.e. less downside risk in bear scenarios, but also less upside potential in bull scenarios).

Section 3 – Switching Costs from CWB to PAB – Orderly Rebalancing

In this section we seek to measure the switching costs of moving from the cap-weighted parent benchmark (STOXX USA 900) to the Paris-Aligned Benchmark (STOXX USA 900 PAB), with an objective to minimize the active risk of the resulting portfolio to the PAB portfolio, subject to a trade-size constraint based on a percentage of the average daily volume (ADV) for the previous 20 days at the asset level. Using Axioma Portfolio Optimizer, we simulate this rebalancing for a range of AUM and maximum threshold levels for the percent-of-ADV trading constraint (i.e., from 1%, 2%, and 5% of ADV), to mimic a realistic rebalancing exercise concerned with market impact. Our goal is to measure the tradeoff between trading too quickly and incurring market impact, versus trading too slowly and incurring tracking error to the target benchmark for the trading period.

Figure 8 on the next page summarizes the rebalancing simulations with varying levels of portfolio AUM and percent-of-ADV constraint. Our objective in these rebalancings is to minimize active risk with the target PAB portfolio in as few trading days as possible. The table shows the results for the first trading day. We see that for

portfolios up to and including AUM levels of USD 500 million, this benchmark switch is feasible with no or very little (0.1%) active risk in a single day, even with a very tight trading threshold constraint of 1% of ADV.

For portfolio sizes of USD 1 billion or more, a tight trading threshold starts to impact the manager's ability to switch benchmarks without incurring active risk for a day. But even at USD 5 billion and with a 1% of ADV trading constraint (bottom row in Figure 8), the tracking error carried over on that day is just 1.1% annualized, which translates to a risk of deviating from the target PAB portfolio return by 0.074% for that day. The second day's trading would bring the active risk almost to 0, so the active risk is only incurred for a single day. Loosening the ADV trading constraint rapidly brings down the active risk the manager would incur, but obviously increases the cost to trade.

Figure 8 – CWB to PAB Rebalancing with Percent of ADV Constraint

TURNOVER SUMMARY	HOLDINGS			ACTIVE	TWO-WAY	TOTAL	BUY	BUY	TOTAL	SELL	SELL
STRATEGY (AUM,%ADV)	INITIAL	FINAL	DELTA	RISK	TURNOVER	BUY	MORE	NEW	SELL	SOME	ALL
CWB - PAB (FULL)	900	679	-221	0%	69%	232	213	19	687	447	240
CWB - PAB (100M, 5%ADV)	900	679	-221	0%	69%	232	213	19	687	447	240
CWB - PAB (100M, 2%ADV)	900	679	-221	0%	69%	232	213	19	687	447	240
CWB - PAB (100M, 1%ADV)	900	679	-221	0%	69%	232	213	19	687	447	240
CWB - PAB (500M, 5%ADV)	900	679	-221	0%	69%	232	213	19	687	447	240
CWB - PAB (500M, 2%ADV)	900	679	-221	0%	69%	232	213	19	687	447	240
CWB - PAB (500M, 1%ADV)	900	752	-148	0.1%	69%	229	212	17	688	523	165
CWB - PAB (1B, 5%ADV)	900	679	-221	0%	69%	232	213	19	687	447	240
CWB - PAB (1B, 2%ADV)	900	752	-148	0.1%	69%	229	212	17	688	523	165
CWB - PAB (1B, 1%ADV)	900	693	-207	0.4%	65%	242	233	9	667	451	216
CWB - PAB (5B, 5%ADV)	900	693	-207	0.4%	65%	242	233	9	667	451	216
CWB - PAB (5B, 2%ADV)	900	688	-212	0.8%	53%	296	292	4	608	392	216
CWB - PAB (5B, 1%ADV)	900	818	-82	1.1%	38%	324	322	2	578	494	84

Source: Axioma Portfolio Optimizer

In conclusion for this section, we find that even for large portfolios with AUM of up to USD 5 billion, the decision to switch from a cap-weighted benchmark to a climate-aligned one does not seem to come with large tracking error costs and can be executed even with tight trading constraints.

But what if several portfolio managers decide to execute this switch on the same day? No portfolio is an island. In the next section we stress test financial markets by simulating the market impact of having large amounts of AUM execute this trade within a single day.

Section 4 – Market Impact Costs from Disorderly Rebalancing

One of the risks that concerns regulators when contemplating an industry-wide move from one benchmark to another due to impending regulations is the market impact of so many similar trades. To answer this question, we use the Goldman Sachs Shortfall Model (market impact model) in the Axioma Portfolio Optimizer. Market impact here is reported as execution shortfall, which is the adverse price move estimated from the volume of trades, as large sell orders push prices down and large buy orders push prices up. We model this market impact from two angles.

First, from the investors' point of view, we aggregate their trades into a very large AUM level but with a rebalancing objective that constrains the maximum level of market impact to 10 bps of the aggregate portfolio's value. We then measure the optimal achievable turnover for this market impact (i.e., how close can we get to the target PAB portfolio if we want to limit the price impact to just 10 bps by all trading together)[13].

Second, we attempt to quantify the aggregate cost to financial markets in terms of market impact to the aggregate portfolio, if large amounts of AUM decide to wait until the last regulatory minute to achieve climate-impact compliance and execute the full rebalancing in a single day.

Figure 9 – Turnover Achieved for 10 bps of Market Impact

MARKET IMPACT (MAX 10 BPS)	TURNOVER ACHIEVED	% OF TARGET
TARGET	69%	100%
USD 100M	69%	100%
USD 500M	69%	100%
USD 1B	69%	100%
USD 5B	51%	74%
USD 10B	39%	57%
USD 50B	22%	32%
USD 100B	18%	25%
USD 200B	14%	20%

Source: Axioma Portfolio and Goldman Sachs Shortfall Model

Figure 9 above shows the turnover achieved at different AUM levels for a rebalancing with a maximum market impact constraint of 0.1% of the portfolio's value. The first row in the table is the target rebalancing from the cap-weighted STOXX USA 900 to the STOXX USA 900 PAB portfolio. To complete the switch from the CWB to the PAB, investors would need to trade 69% (two-way turnover) of the value of their portfolio, as we saw earlier in Section 3.

As was the case in Section 3 for the rebalancing with the ADV trading constraint, 100% of the target two-way turnover can be achieved, without breaching the 0.1% market impact constraint for aggregate portfolio value up to USD 1 billion. For an aggregate AUM of USD 5 billion, however, only 51% of the targeted turnover can be achieved for that market impact in a single day. The previous 20-day average daily volume across all constituents of the STOXX USA 900 as of September 30, 2020 was about USD 336 billion. We can therefore easily imagine that some USD 100 billion, or less than a third of the day's average volume, could be climate-compliance related as we near the regulatory deadline. Under that scenario, only 25% of the necessary turnover could be achieved for a market impact cost of 0.1%. It would take a minimum of four days for an aggregate AUM of USD 100 billion to execute this trade at the cost of 0.1% of market impact each day.

[13] This is the quant equivalent of asking how much (turnover) bang we can get for the (market impact) buck.

Figure 10 below shows the total unconstrained market impact incurred by different levels of aggregate AUM all trying to complete the 69% target turnover in a single day. Again, we see that the market impact costs are negligible for aggregate AUM below USD 1 billion. Above that level, costs start to rise rapidly.

Trying to rebalance an aggregate AUM of USD 100 billion in a single day would cost over USD 627 million in market impact[14], representing a loss of 0.6% of the aggregate portfolio's value. In other words, more than half of our naïve *'climate transition active risk premium'* of 1.15% would be wiped out by careless trading—and that is before any additional trading costs (e.g. commissions, etc.)!

Figure 10 – Market Impact Cost of Full Rebalancing in a Single Day – September 30, 2020

MARKET IMPACT (MAX 10 BPS)	MARKET IMPACT (BPS)	MARKET IMPACT (USD)
TARGET	0.0%	N/A
USD 100M	0.0%	$ 249,121
USD 500M	0.0%	$ 464,943
USD 1B	0.1%	$ 658,348
USD 5B	0.2%	$ 7,587,435
USD 10B	0.2%	$ 21,648,184
USD 50B	0.5%	$ 244,942,744
USD 100B	0.6%	$ 627,087,650
USD 200B	0.7%	$ 1,339,175,394

Source: Axioma Portfolio Optimizer and Goldman Sachs Shortfall Model

We also note that market impact is 'impacted' by the then-current volatility regime. This analysis was conducted using data for September 30, 2020, when the Axioma US4-SH model was predicting a volatility of 20.7% and an active risk of 2.47%. We conducted the analysis again as of June 22, 2020, when our models predicted a volatility level of 32% and a higher active risk between the two portfolios of 3.11%.

Figure 11 shows the resulting market impact under that higher volatility regime, although the required turnover was similar on that date (69%). An aggregate AUM of USD 100 billion would now have to bear USD 750 million in market impact cost, representing a loss of 0.75%. If a total of USD 200 billion of climate transition trades were to go through on that date, the market impact costs would total USD 2.1 billion, or 1.1% of the aggregate portfolio's value, all but wiping out our initial '*climate transition active risk premium*' of 1.15%.

[14] Note that since all trades will be executed in the same direction for all investors, t-costs are probably higher than what the model predicts, and prices will drop substantially.

Figure 11 – Market Impact Cost of Full Rebalancing in a Single Day – June 22, 2020

MARKET IMPACT (MAX 10 BPS)	MARKET IMPACT (BPS)	MARKET IMPACT (USD)
TARGET	0.0%	N/A
USD 100M	0.0%	$ 266,280
USD 500M	0.1%	$ 501,984
USD 1B	0.1%	$ 708,808
USD 5B	0.2%	$ 8,161,846
USD 10B	0.2%	$ 23,306,230
USD 50B	0.5%	$ 264,043,342
USD 100B	0.7%	$ 749,158,156
USD 200B	1.1%	$ 2,123,600,863

Source: Axioma Portfolio Optimizer and Goldman Sachs Shortfall Model

In conclusion for this section, investors must keep in mind the market impact cost of having many portfolios rebalance toward the same target. Regulations pulling investors toward climate impact investing are the same for all investors, therefore portfolio managers are unlikely to be trading alone. Neither is new liquidity created because of these regulations. The liquidity of today is what it is—all the best an investor can hope to do is to trade efficiently. If the tradeoff is between market impact and incurring diminishing tracking error to the target benchmark over a week or two, given these potential market impact costs, portfolio managers may want to opt for tracking error instead.

Note that these conclusions hold true for a rebalancing decision made today (in 2020). The construction of the PAB started with the goal of having 50% less carbon emission than its CWB parent, but then calls for an ongoing 7% year-on-year improvement in the decarbonization rate. This means that companies with business models that fail to deliver this incremental decarbonization will be down-weighted in the PAB index, while those that deliver on this metric will get progressively over-weighted. As a result we can expect the current active risk between the CWB and the PAB to actually increase over time as 'brown' companies remain in the CWB but are down-weighed in the PAB in favor of ones with 'green' business models. As such, we can expect the active risk and turnover involved in switching from one to the other to gradually increase each year from the current 2.47% and 69%, respectively. This, in turn, means that waiting to rebalance from a CWB to a PAB portfolio will be even costlier than this analysis suggests, due to incremental turnover as time goes by.

Final Thoughts

Climate impact investing is not a fad, it is a regulatory reality hurtling towards non-compliant portfolios. In some jurisdictions, this will come as soon as March of next year[15]! And it represents a thematic risk premium that investors can harvest between now and when regulations come into effect. But as with any existing risk premium, a disciplined portfolio construction and rebalancing process is key.

From our analysis we make the following observations. First, there is a sizeable gap between the current cap-weighted benchmarks and climate-aligned ones. The switch from one to the other represents about 2-3% in tracking error and will require about 69% in turnover in the case of the STOXX USA 900 and its PAB variant. Executing this trade will not come cheap to those who are impatient. In addition, as time goes by, more and more of one's peers can be expected to be heading in the same direction, driving execution costs even higher and prices lower. So, who will buy your brown industry stock a week ahead of regulatory changes requiring climate-alignment of your portfolio? For a preview of what crowding may look like, replay the Quant crash of July-August 2007[16] on your portfolio.

On the bright side, a switch to a climate-aligned benchmark does not seem to come with any hidden (bad) surprises in terms of downside or tail risk. In all of the stress tests we ran on both portfolios, cap-weighted and climate-aligned, we found no major sensitivities of concern that could not be easily identified, explained, monitored, or hedged, if need be.

In conclusion, investors considering a move to a climate-aligned benchmark should do it slowly, but do it early[17]. When it comes to climate-impact investing, no good thing comes to those who wait for the carbon bubble to burst — only the market impact left behind by those who hustled.

[15] Regulation (EU) 2019/2088 of the European Parliament and of the Council of 27 November 2019 on sustainability-related disclosures in the financial services sector. The disclosures regulation was adopted by co-legislators in spring 2019 and was published on 9 December 2019 in the Official Journal. It is already in force but will apply from 10 March 2021.
[16] Between July 19 and August 3, 2007, the S&P 500 fell 8%, which was attributed mainly to trade crowding.
[17] These findings are echoing the more macro-economic approach to the fight against climate change, which highlights the strong global benefits associated with early actions: cf. executive summary of the Stern review: https://institutional.union-investment.de/dam/jcr:1c7bb015-0aa3-4a4c-958c-f41f0f551a9d/Stern%20Review%20-%20The%20Economics%20of%20Climate%20Change.pdf