Climate VaR and Financial Value

Assessing the Empirical Evidence

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In this study, we tested how climate value at risk (CVaR) performs as a tool to call attention to stocks with elevated physical risk exposure. We aimed to de-risk portfolios by excluding names with elevated climate VaR. While data on CVaR is limited, we found that the so-created "CVaR portfolio" outperformed the benchmark in our sample period[1] because the excluded stocks exhibited much lower returns over the period.

CVaR portfolios have historically outperformed their benchmarks, and the majority of their excess returns can be explained by security selection rather than climate-related sector biases. Importantly, during Climate disasters, the excluded securities significantly underperformed the benchmark and the CVaR Aware portfolio.

Climate Risk and the Goals of Our Analysis

The rise in carbon emissions and the resulting increase in the Earth's surface temperature have led to a greater number of climate-related disasters in recent years, bringing about damages of $742.1 billion in 2017–2021, and net costs of $872.9 billion and $556.8 billion over the 2010s and 2000s, respectively, per NOAA Climate.gov These weather-related disasters have an adverse effect on the functioning of firms within the affected regions. For example, many transportation, agriculture, and oil and gas companies in Louisiana suffered large losses due to Hurricane Ida (see sidebar, "Linking Carbon Emissions and Temperature Rise"). To counter/safeguard against these events in portfolios, we consider various pieces of data, including CVaR, an iteration of the widely used value-at-risk metric.

In this study, we tested how CVaR performs as a tool to call attention to stocks with elevated physical risk exposure. We then excluded those riskiest names from the Russell 1000 Index. While data on CVaR is limited, we found that the so-created CVaR portfolio outperformed the benchmark in our sample period because the excluded stocks exhibited much lower returns over the period. Importantly, during climate disasters, the excluded securities significantly underperformed the benchmark and the CVaR Aware portfolio. Moreover, we observed that only 39 basis points of the 1.5% excess return of the CVaR Aware portfolio over time can be explained by existing factors (see Figure 3, which ties in with the fact that we see only half of the active risk coming from factors).

JEL Classification Codes G11, G12, G14, G32

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CVaR and the Market's Underestimation of Climate Risk

Historically, a wide range of studies have analyzed the relationship between market pricing and climate change. However, many of these studies found that markets underestimated the stock price volatility that can come from climate risks. For example:

- A team from the Federal Reserve Bank of San Francisco tried to identify the economic impacts of extreme weather events on the US market (with a focus on hurricanes). Comparing the ex-ante expected volatility with ex-post realized volatility showed a significant market underestimation of weather uncertainty (though post Hurricane Sandy, the market's estimations improve). The study also observed large underperformance in cumulative stock returns for firms impacted by extreme weather up to six months after the event, relative to the control group.[2]

- Another study attempted to determine whether climate risks are priced into equity securities. This study observed that only *immediate* climate news is accounted for in prices, and any price impacts mostly occurred post 2012.[3] The findings revealed that the risks generated by government intervention (*and not direct risks from climate change*) were priced into the stock market. This could be because: Investors pay attention only when climate risks become an issue for US politics; investors lack information on company exposures to climate risks; and/or investors have a myopic view of risks.

These studies underscore the need for data that can help clients understand the importance of managing climate risks in portfolios.

CVaR as a Data Solution

CVaR is a relatively new concept that measures the "size of loss attributable to climate-related financial risks, by comparing the value of assets in a world with climate change, relative to the same world without climate change".[4] One of the earliest uses of CVaR calculated the value at risk of global financial assets based on two scenarios: (1) a business-as-usual (BAU) scenario (based on a 2.5°C carbon emission mitigation pathway), and (2) an improved scenario based on a 2°C pathway.[5] It observed that 16.86% (roughly USD $24.2 trillion) of financial assets were at risk based on a BAU scenario, and this fell to about 1.77% of financial assets (roughly USD $2.5 trillion) under a 2°C pathway.

The significant increase in CVaR exemplifies the need for detailed value-at-risk scenarios that can inform clients about the historical price volatility related to climate risks and help them monitor tail risks. Notably, these numbers may be conservative given that the latest evidence implies a temperature rise closer to 3–4°C under current policies, based on the Intergovernmental Panel on Climate Change (IPCC) Working Group III reference pathways.[6]

Constructing the CVaR Portfolios

In this study, we aimed to de-risk portfolios by excluding names with elevated climate VaR. Climate VaR is estimated by several financial and environmental, social, and governance (ESG) data vendors, including MSCI and Institutional Shareholder Services (ISS). Most of these vendors align with the Task Force on Climate-related Financial Disclosures (TCFD) recommendations for conducting scenario analysis. For this exercise, we used the value-at-risk metrics provided by MSCI ESG Research, a vendor that used 15 years of securities data to form a calculation of climate VaR. MSCI calculates CVaR for each individual issuer, under various scenarios.

Universe of Names

For the benchmark index, we used the Russell 1000 Index constituents and their weights. Restricting the index to US-only securities provides several advantages: One, it helps to ensure steady coverage of the index. The CVaR coverage (in terms of market cap) at the beginning of our sample period (2018) is about 91.7%, and this rises steadily to about 98.4% in 2022. Two, using US-only securities can help restrict country-specific factors. Finally, the US has a diverse topography that provides a more accurate assessment of the relative effects of climate disasters, as opposed to countries with more even topographies and the same extreme weather occurring countrywide. For example, Japan, as a whole, is particularly vulnerable to natural disasters.[7]

However, we also performed our analysis on issuers in the MSCI World Ex-US Index to test the predictive power of CVaR for international portfolios. We have included results of that exercise in Appendix A.

The MSCI Data Set

MSCI provides value-at-risk metrics related to physical risks, policy risks, and technological opportunities. For this exercise, we restricted ourselves to *physical* risks, given that these are readily observable today. By contrast, many of the transition risks and technological opportunities (countrywide government policies, carbon pricing, and green innovations, among others) are likely to emerge in the future, as many countries are still taking a soft stance on the issue. (For more information on physical risks and physical risk data, see: Physical Climate Risk Data: A Primer and Evaluation).

For MSCI, expected costs of physical risks are calculated as a function of vulnerability (cost function), hazard (type of weather event), and exposure (location and allocation of company facilities).[8] MSCI calculates costs under various scenarios. For our analysis, we used the aggressive physical scenario, which is based on a Representative Concentration Pathway 8.5 (corresponding to about a 4.3°C increase in temperature by the year 2100).

MSCI CVaR provides an equity's upside or downside potential (as a percentage of market value) assuming trends in extreme cold, extreme heat, extreme precipitation, heavy snowfall, extreme wind, coastal flooding, fluvial flooding, tropical cyclones, and low river flow. The values can theoretically range from -100% to +100%; however, positive CVaR numbers are quite rare and represent a *reduction* in current costs due to a given weather effect. For example, a positive CVaR could indicate easier transportation due to a decline in snowfall. We used the latest available CVaR data set, which is as of May 31, 2022. This represents the latest scores with model updates, and provides an updated outlook with maximum security coverage.

While one should ideally use historical, point-in-time CVaR for back-testing purposes, the history available for this metric is limited. Hence, we used the security-level CVaR as of May 31, 2022, and backfilled the data. While this might be seen as creating a forward-looking bias, we made this modeling choice for multiple reasons:

1. The underlying data that goes into the computation of CVaR is relatively static.

2. As a relatively new metric, any historical data available would be backfilled with any missing data, and therefore runs the risk of being overfitted.

3. As a new metric with limited history available, a portfolio constructed with current data filled historically should give more information than a point-in-time analysis.

CVaR Scores

We used these issuer CVaR scores to identify the securities most likely to be affected by extreme weather events. We then calculated portfolio CVaR scores for (1) a de-risked portfolio excluding these names, (2) the benchmark, and (3) a portfolio solely including the excluded securities, using MSCI data from a four-year testing period. The three portfolio CVaR scores were calculated using the equation in Figure 1. The equation states that the CVaR of the portfolio can be calculated by using the weighted average of the security CVaR. We assessed the risk-return characteristics of each of the three portfolios to determine the efficacy of CVaR.

Figure 1
Overall Portfolio CVaR Scores Use Weighted Average Metrics for Individual Securities

$$VaR_p = \frac{\sum_q VaR_q * W_q}{\sum_q W_q}$$

Where: VaRq is the climate value at risk for security q; Wq is the weight of q in the portfolio.

Sector Controls

Climate risks have significant sector-by-sector impacts, so we also controlled for sector deviations. For example, if one were to exclude the bottom CVaR decile with no sector adjustments, as many as 38% of utilities in the index would get excluded (Figure 2).

Figure 2
CVaR Breakdown by Sector Illustrates Industry-Specific Climate Risks

Sector	Total Names	Names in Bottom VaR Decile	% Names in Bottom VaR Decile	% Weight in Bottom VaR Decile	Weighted Average CVaR
Communication Services	61	7	11	11	-0.50
Consumer Discretionary	140	8	6	2	-0.22
Consumer Staples	58	18	31	27	-0.73
Energy	47	7	15	5	-0.26
Financials	151	8	5	3	-0.52
Health Care	134	6	4	3	-0.59
Industrials	164	11	7	4	-0.42
Information Technology	184	6	3	0	-0.38
Materials	59	4	7	8	-0.12
Real Estate	84	7	8	4	-0.12
Utilities	39	15	38	38	-0.36

Source: State Street Global Advisors, MSCI. Weighted average CVaR per sector, and exclusions based on naive approach (as of March 2022).

Thus, we adopted best- and worst-in-class screening approaches within every sector, since CVaR is built as a risk measure. The detailed methodology was as follows:

- Separate securities that do not have CVaR data into bucket B1. The remaining securities are in bucket B2.
- For bucket B2, calculate the weight of every sector.
- Within every sector in B2, select the top 80% of securities based on CVaR ranking (i.e., the 80% of securities with the lowest CVaR). Distribute the weight of the excluded securities proportionally to the selected securities, so that the sector remains at benchmark weight. The resulting portfolio is B2'.
- Combine B2' with B1. In this way, form our de-risked portfolio (referred to as the *CVaR Aware portfolio*) while keeping the sector weights aligned with the benchmark's. To further study the effect of exclusions, we also built a worst-in-class portfolio by following the same methodology, but selecting the bottom 20% of the securities (referred to as the *CVaR Exclusions portfolio*).

Results of Our Analysis

Our analysis showed that the CVaR Aware portfolio has lower CVaR, a higher return, and a higher risk-adjusted return (Sharpe ratio) versus the benchmark and the CVaR Exclusions portfolio over our sample period. Furthermore, the Exclusions portfolio performed worse than the benchmark. Specifically, throughout the rebalance period, for each month, the CVaR Aware portfolio outperformed on a rolling 12-month basis.

Since the sector weights do not differ between the benchmark and the portfolios, we can conclude that all of the return differentials are driven by selection effects, rather than sector weights. This underscores that incorporating Climate VaR can be useful in reducing portfolio risk and improving returns.

Figure 3
The CVaR Aware Portfolio Exhibited a Higher Sharpe Ratio
Portfolio analysis of the Russell 1000 (back-tested returns, June 2018 to March 2022)

Performance Metrics	CVaR Aware Portfolio	CVaR Exclusions Portfolio	Russell 1000 Index
Return (%)	17.97	5.88	16.44
Risk (%)	18.21	21.01	18.25
Sharpe Ratio	0.99	0.28	0.90
Excess Return (%)	1.53	-10.57	—
Tracking Error (%)	0.88	7.94	—
Information Ratio	1.73	-1.33	—
Max Drawdown (%)	-19.57	-30.20	-20.31
Beta	1.00	1.07	—
Average Number of Names	903	358	—
Average Active Factor Risk (%)	51.38	54.93	—
Weighted CVaR (%)	-3.01	-17.02	-4.69

Source: State Street Global Advisors, MSCI. Russell 1000 Index returns are unmanaged and do not reflect the deduction of any fees or expenses. Russell 1000 Index returns reflect all items of income, gain, and loss and the reinvestment of dividends and other income as applicable. The data displayed for the Russell 1000 Index is a hypothetical example of back-tested performance for illustrative purposes only.
Back-tested results are not indicative of the past or future performance of any State Street product. The portion of results through June 30, 2018, represent a back-test of the CVaR Aware, CVaR Exclusions, and Russell 1000 Index portfolios, which means that those results were achieved by means of the retroactive application of the model, which was developed with the benefit of hindsight. Data displayed beyond this date is not back-tested, but is generated by the model. All data shown above does not represent the results of actual trading, and in fact, actual results could differ substantially, and there is the potential for loss as well as profit. Please reference the Back-tested Methodology Disclosure for a description of the methodology used as well as an important discussion of the inherent limitations of back-tested results.

Performance During Periods of Extreme Weather

We also examined the returns of the three portfolios during periods of climate disasters.

- From June to October 2021, the US suffered a heat wave and experienced Hurricane Ida. During this period (both months inclusive), the CVaR Aware portfolio returned 86 bps over the benchmark, with a return of 8.06%, while the CVaR Exclusions portfolio returned 850 bps below the benchmark, with an absolute return of -1.3%.

- During the Mississippi and Missouri River floodings from March to July 2019, the CVaR Aware and CVaR Exclusions portfolios returned 8.4% and 2% respectively, versus the Russell 1000 Index return of 7.7%.

Implicit Style Bias

To uncover any implicit exposure to non-climate-related style factors that may be separately driving returns, we calculated factor return attribution for these portfolios. We observed that only 39 bps of the 1.5% excess return of the CVaR Aware portfolio over time can be explained by existing factors (Figure 3, which connects to the fact that we see only half of the active risk coming from factors. However, given that we used the available data set as of May 2022, we remind readers of the potential for a forward-looking bias.

Conclusions

In this piece, we explored the impact of integrating climate VaR into portfolio construction. We found that prima facie, CVaR adds value and captures information not proxied by existing metrics. We support repeating this exercise after a sufficient period in which live climate VaR data is available. In this way, climate experts, investors, and data vendors can determine whether the effectiveness of the metric has staying power in future years.

The outperformance of the CVaR Aware portfolio provides an argument for the consideration of climate risks in portfolios. As investors and companies face new climate regulations, evolving net-zero targets, and frequent extreme weather operating challenges, CVaR is just one example of the ways data can help market participants understand the scope of climate risks in their portfolios (see: Examining the Properties of Forward-Looking Climate Metrics). We look forward to continuing to help our clients manage and understand climate risks and translate their regulatory obligations and risk management objectives into implementable actions.

Endnotes

1 June 2018 to March 2022.

2 Mathias S. Kruttli, Brigitte Roth Tran, and Sumudu W. Watugala, "Pricing Poseidon: Extreme Weather Uncertainty and Firm Return Dynamics," Federal Reserve Bank of San Francisco Working Paper (2021–23).

3 Renato Faccini, Rastin Matin, and George S. Skiadopoulos, "Dissecting Climate Risks: Are they Reflected in Stock Prices?" *SSRN* (2021).

4 The Economist Intelligence Unit, "The Cost of Inaction: Recognising the Value at Risk from Climate Change," *Economist Impact* (2015). Appendix written by Vivid Economics.

5 Simon Dietz, Alex Bowen, Charlie Dixon, and Philip Gradwell, "'Climate value at risk' of global financial assets," *Nature Climate Change,* 6(7), (2016): 676–679. https://doi.org/10.1038/nclimate2972.

6 Intergovernmental Panel on Climate Change, "IPCC Sixth Assessment Report: Climate Change 2022: Mitigation of Climate Change," USA: Cambridge University Press (2022).

7 Ministry of Foreign Affairs Japan, "Disasters and Disaster Prevention in Japan." https://mofa.go.jp/policy/disaster/21st/2.html.

8 MSCI ESG Research LLC, "MSCI Climate VaR Methodology" (2021).

Appendix A:

Application of the Methodology on an International Portfolio

We also analyzed returns for the CVaR Aware and CVaR Exclusions portfolios using names from the MSCI World Ex-US Index. In this way, we considered whether CVaR can provide viable results in a non-US context. For future studies, we support further exploration of whether the CVaR metrics observed can be replicated in regions with different economic structures and environmental regulations.

Our performance outcomes for the MSCI World Ex-US were similar to the Russell 1000 Index results. Specifically, the CVaR Exclusion portfolio performed unfavorably relative to the MSCI World Ex-US Index and the CVaR Aware portfolio (Figure 4).

In this analysis, the CVaR Aware portfolio also performed better than the benchmark and CVaR Exclusion portfolio during periods of drawdown.

Figure 4
The CVaR Aware Portfolio Performed Similarly in a Non-US Context
Portfolio analysis of the MSCI World Ex-US (back-tested returns, June 2018 to March 2022)

Performance Metrics	CVaR Aware Portfolio	CVaR Exclusion Portfolio	MSCI World Ex-US
Return (%)	8.55	-2.67	7.03
Risk (%)	17.05	17.69	16.95
Sharpe Ratio	0.50	-0.15	0.41
Excess Return (%)	1.52	-9.70	—
Tracking Error (%)	1.01	6.26	—
Information Ratio	1.51	-1.55	—
Max Drawdown (%)	-22.41	-31.27	-22.96
Beta	1.00	0.97	—
Average Number of Names	765	241	—
Weighted CVaR (%)	-7.80	-42.82	-12.62

Source: State Street Global Advisors, MSCI. MSCI World Ex-US Index returns are unmanaged and do not reflect the deduction of any fees or expenses. MSCI World Ex-US Index returns reflect all items of income, gain, and loss and the reinvestment of dividends and other income as applicable. The data displayed for the MSCI World Ex-US Index is a hypothetical example of back-tested performance for illustrative purposes only.
Back-tested results are not indicative of the past or future performance of any State Street product. The portion of results through June 30, 2018, represents a back-test of the CVaR Aware, CVaR Exclusion, and MSCI portfolios, which means that those results were achieved by means of the retroactive application of the model, which was developed with the benefit of hindsight. Data displayed beyond this date is not back-tested, but is generated by the model. All data shown above does not represent the results of actual trading, and in fact, actual results could differ substantially, and there is the potential for loss as well as profit. Please reference the Back-tested Methodology Disclosure for a description of the methodology used as well as an important discussion of the inherent limitations of back-tested results.

Linking Carbon Emissions and Temperature Rise

In the 19th century, the industrial revolution spurred many economists to worry about the decline of coal resources and argue for the more efficient use of coal. As a result, the cost of coal dropped, and demand increased — a rebound effect known as "Jevons Paradox".[1] Fossil fuel energy demand skyrocketed by more than 2,000% from the 1860s (the brink of the industrial revolution) to the 2000s.[2] The resulting substantial carbon emissions trap heat within the atmosphere and raise the global temperature. The average surface temperature rose by approximately 1.1°C from the 1880s to 2017, with a further threshold of 420 billion tons of CO_2 until the temperature will arrive at 1.5°C, according to the Intergovernmental Panel on Climate Change (IPCC). Given average yearly emissions of 40 billion tons, this 420 billion threshold does not seem far off. According to two potential IPCC Assessment Report 6 (AR6) pathways, the "Current Policy" and "Moderate Action Reference" pathways, this point could be reached by 2030 (Figures 5 and 6).[3] The IPCC Special Report lists five "reasons for concern" associated with increasing temperature, with most of them being demarcated as high-moderate risks at a 1.5°C mark:[4]

1. Unique and threatened systems
2. Extreme weather events
3. Distribution of impacts
4. Global aggregate impacts
5. Large-scale singular events

1 "The Jevons Paradox and Rebound Effect: Are we implementing the right energy and climate change policies?" The OECD Forum Network, September 22, 2022. https://oecd-forum.org/posts/the-jevons-paradox-and-rebound-effect-are-we-implementing-the-right-energy-and-climate-change-policies.
2 Andreas Malm, *Fossil Capital: The Rise of Steam Power and the Roots of Global Warming*. Verso Books, 2016.
3 Edward Byers et al., "AR6 Scenarios Database (1.0)" [Data set], Zenodo (2022). https://doi.org/10.5281/ZENODO.5886912.
4 IPCC, "Special Report: Global Warming of 1.5° C," Figure SPM.2. https://ipcc.ch/sr15/chapter/spm/b/spm2/.

Figure 5
Under Current Policies, Carbon Emissions are Expected to Continue Rising*

CurlPol AR6 Climate Diagnostics | Infillied | Emissions | CO_2 Mt CO_2/yr

ModAct AR6 Climate Diagnostics | Infillied | Emissions | CO_2 Mt CO_2/yr

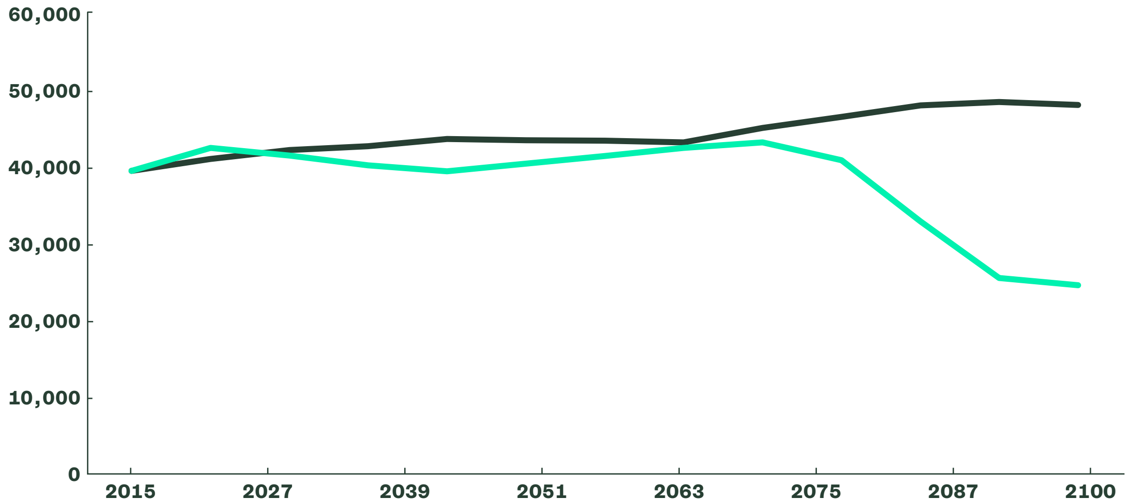
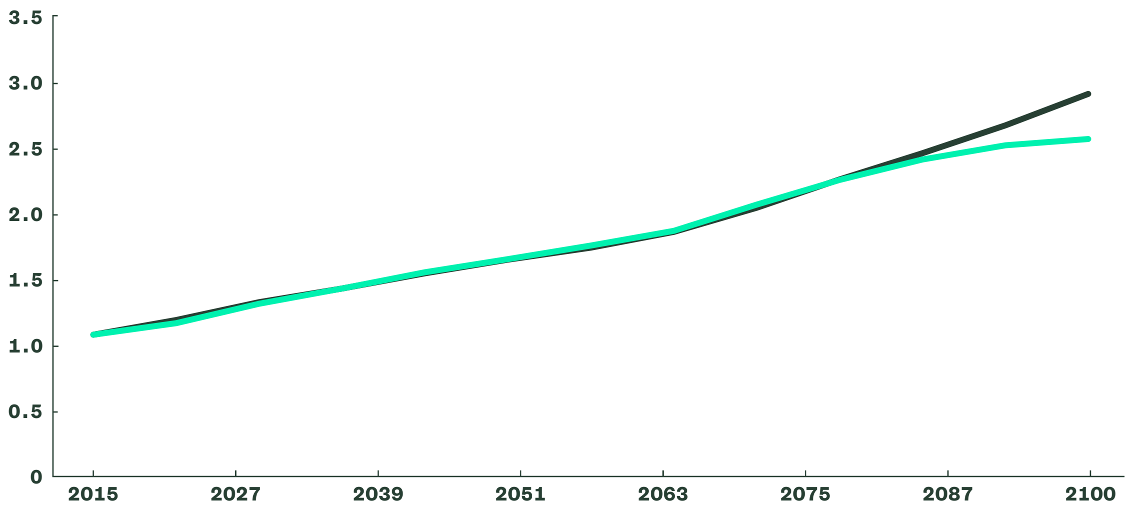


Figure 6
Surface Temperatures Poised to Exceed 1.5% in Early 2030s*

CurPol AR6 Climate Diagnostics | Surface Temperature (GSAT) | MAGICCv7.5.3 | 50.0th Percentile | Kelvin K

ModAct AR6 Climate Diagnostics | Surface Temperature (GSAT) | MAGICCv7.5.3 | 50.0th Percentile | Kelvin K



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* Pensions & Investments Research Center, as of December 31, 2021.
† This figure is presented as of December 31, 2022 and includes approximately $58.60 billion USD of assets with respect to SPDR products for which State Street Global Advisors Funds Distributors, LLC (SSGA FD) acts solely as the marketing agent. SSGA FD and State Street Global Advisors are affiliated. Please note all AUM is unaudited.