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Sustainable Portfolios Under Climate Change: A Framework for Managing Investment-related Climate Change Risks

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Global climate change is posing a complex set of emerging risks to both insurance companies and pension funds. While the impact of climate change on insured risks has gained some attention among actuarial organizations, relatively little interest is directed toward the asset side of the balance sheet. This article summarizes the key findings of a recent research study sponsored by the Society of Actuaries on investment-related climate change risk, with a focus on risk quantification, management and construction of sustainable portfolios under the changing climate.[1] For simplicity, the scope of discussion is limited to equity investments, but the conclusions and methods presented here can be extended to fixed income, alternative investments and other derivatives.

HOW DOES CLIMATE CHANGE AFFECT INVESTMENT RETURNS?

Climate change impacts an investment portfolio through two channels: first, it directly elevates weather-related physical risk to real properties and infrastructure assets, which extends to increased market risk in equity holdings with material business exposures in climate-sensitive regions. Second, it indirectly triggers stricter environmental regulations and higher emission costs in a global effort for emission control, which induces downturns in carbon-intensive industries in which a portfolio may have material positions. In the latter case, climate change is effectively transformed into a political risk affecting particular asset classes and is often referred to as the investment carbon risk.

PORTFOLIO DECARBONIZATION: A VISION FOR THE FUTURE

Due to the gradual yet irreversible nature of global warming, managing the climate change risk in investments is a long-term strategy that requires prudent considerations into the next 30 or 50 years. This poses a significant challenge to risk quantification using standard actuarial approaches. Instead, a combination of visions, theories and cross-disciplinary models are needed. The result of portfolio climate change risk management is an optimal asset allocation where we move away from sectors expected to underperform in the climate change scheme (e.g., the carbon-intensive sectors), while putting more stakes in the ones expected to outperform. This leads to a process called portfolio **decarbonization**. While the term is self-explanatory, it is based on two major premises that can be verified empirically:

1. Carbon risk has not yet been priced by the stock market in carbon-intensive industries, which shall experience downturns when the risk pricing takes place.

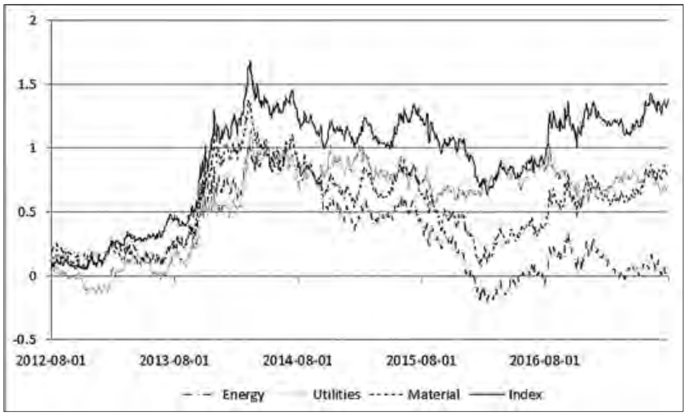
2. The carbon-intensive industries do not provide strong enough returns to be considered indispensable portfolio return enhancers.

The first premise can be verified by an inter-temporal analysis of stock returns for a sample of 36 publicly traded large emitters and related sector indices from Europe and North America around the ratification of major climate protocols (i.e., the implementation of the European Union Emissions Trading Scheme and the ratification of the Paris Agreement). A linear factor model is used to filter out the systematic portion of returns. Event study techniques and statistical testing are conducted to detect structural downward shifts in stock returns around the aforementioned regulatory events, which imply market pricing of carbon risk. Under this approach, only nine out of the 36 samples displayed recognizable carbon pricing.

> Climate change… indirectly triggers stricter environmental regulations…

The second premise can be verified by comparing the historical performance of the emission-heavy sectors (e.g., energy, utilities and material) against those of the other sectors. Risk-adjusted returns measured using Sharpe and Treynor ratios[2] are calculated on both a rolling window and an average basis. The carbon-intensive sectors consistently ranked at the bottom of the list across the metrics and underperformed the market indices for both Europe and North America. As an illustration, Figure 1 (Pg. 19) shows the five-year rolling Sharpe ratio for U.S. sector and benchmark indices. Notice the lines representing the three emission-heavy sectors' returns near the bottom of the chart, which are well below the red line representing the S&P 500 index.

Figure 1
Five-Year Rolling Sharpe Ratio for U.S. Carbon-intensive Sector and Benchmark Indices



RISK MEASUREMENT AND QUANTIFICATION

We focus on three risks for which quantitative measurements are developed.

Carbon Risk

Carbon risk is a general term referring to the risk in an investment or portfolio by having significant stakes in emission-heavy companies. Carbon risk of a stock is best measured by the carbon intensity of the issuing company, which is basically the company's average normalized annual emission amount where the normalization factor may be the annual sales or profit Figure (must be positive). The latter is preferred since the net profit portion of the earnings should directly contribute to stock value. The required financial information is readily available, while the emission figures for most large public companies are available on the CDP (formerly the Carbon Disclosure Project)[3] database. The carbon risk of a portfolio is measured by a weighted average of the carbon intensities of the constituents.

Stranded Asset Risk

Stranded assets refer to a broad class of assets that may not deliver the expected returns due to regulatory, technological and other socio-economic reasons related to the climate change risk. For instance, many fossil fuel (e.g., coal, oil or gas) reserves cannot be deployed further due to regulatory emission caps or heavy taxation. Hence, capital invested today in future oil, gas and coal production is at risk of being stranded, leading to significantly reduced returns from those originally expected. This translates to asset devaluation and stock price depreciation, which we refer to as stranded asset risk. Quantification of SAR requires modeling at the individual stock level and therefore requires much effort. In general, SAR is driven by three factors: the probability that the asset becomes stranded, the percentage loss in asset value given the stranding and the recoverable amount. Our suggested method adopts a parametric approach to model a threshold exploitation level beyond which the fuel reserve becomes stranded. For brevity, the details are not presented here. Interested readers can refer to our report for more details.

Climate Change Risk

Unlike carbon and stranded asset risks, climate change risk may be quantified at the sector level or at the individual stock level. Quantification of climate change risk requires a scenario-based approach using integrated assessment models and subjective inputs. IAM is a set of scientific models used in environmental sciences and environmental modeling, integrating knowledge and methodologies across multiple disciplines. The approach requires several steps:

1. Select climate change risk factors and IAM.
2. Assign factor sensitivities for each stock or sector considered.
3. Select a projection horizon over which the portfolio is managed.
4. Generate factor value scenarios using the selected IAM for the projection horizon.
5. For each stock/sector under each scenario:
    a. Convert the factor values, at each projection point, to climate risk exposure given by the sum product of the sensitivities and the corresponding factor values.
    b. Calculate the change in CRE between the current point and a target end date for the portfolio.
    c. Convert the CRE difference to stock return impacts using proper grading methods.
6. Average the estimated return impacts across scenarios.

There are several technical considerations at play here. For example, the factors of interest may be represented by different output variables available from the selected IAM, whose simulated values must be properly mapped to relative scales to allow proper calculations (i.e., we cannot add Celsius degrees to dollar prices of emission abatements). Linear transformations can be used as the simplest case, while more complex factor paths must be captured using nonlinear models. We do not discuss these details here. Tables 1, 2 and 3, and Figure 2 are excerpts from an illustrative example used in our report based on the World Induced Technical Change Hybrid, or WITCH, model,[4] one of the most commonly used IAMs. Factor values are obtained using linear grading of selected proxy output variables under each scenario, while the conversion of CRE differences to return impacts are done using piecewise-linear mapping. Stocks in the same sector are assumed to have the same risk exposures.

Table 1
Sample Climate Change Risk Factors

Company	Description	Proxy 1	Proxy 2
Technology (T)	The rate of progress and investment in the development of technology to support the low-carbon economy	Investment in advanced biofuel (USD)	Investment in energy efficiency (USD)
Political (P)	The coordinated developments in climate policy to reduce carbon emissions	Greenhouse gas abatement (ton CO_2/yr)	None
Climate Impact (C)	Tangible impacts from shifts in extreme weather incidence and severity, as well as resources that are at risk of becoming scarcer or, in rarer cases, more abundant	Radiative forcing (RF) (W/m^2)	Global mean temperature change (deg Cel)

Table 2
Sample Sector Level Sensitivities to Factors in Table 1

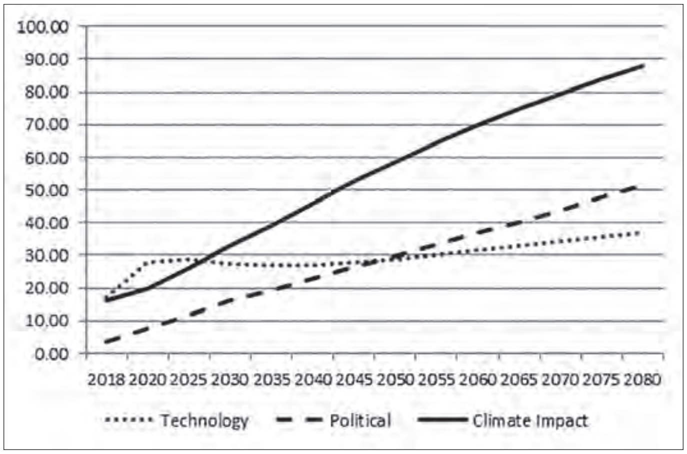
Industry Sector	T	C	P
Consumer discretionary	0	0	–0.25
Consumer staples	0	–0.25	0
Energy	–0.5	–0.5	–1
Financials	0	–0.25	0
Health care	0.25	–0.25	0
Industrial	0	–0.75	–0.5
Information technology	0.25	0	0
Materials	0.25	–0.25	–0.75
Real estate	0	–1	0
Telecommunications	0	–0.25	0
Utilities	–0.25	–0.5	–0.75

Table 3
Sample Climate Change Risk Quantification

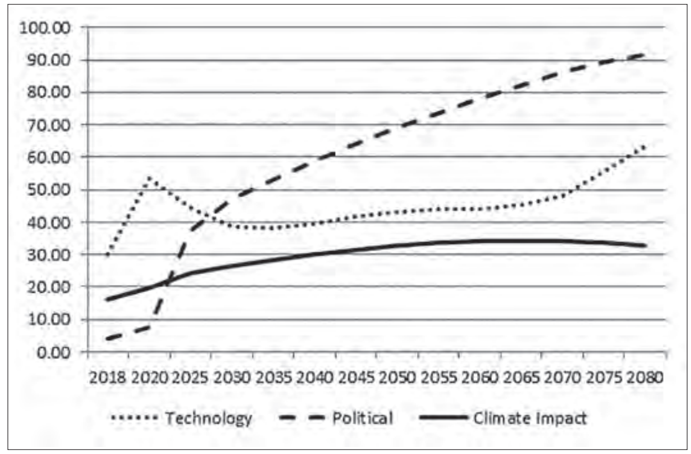
Industry Sector	ΔCRE	Δr (annual)
Consumer discretionary	8.14	–0.0814%
Consumer staples	7.92	–0.0792%
Energy	115.53	–2.7553%
Financials	18.80	–0.1880%
Health care	7.92	0.2790%
Industrial	84.48	–1.0448%
Information technology	–10.88	0.6088%
Materials	50.06	–0.9006%
Real estate	75.18	–1.5518%
Telecommunications	18.80	–0.1880%
Utilities	90.61	–1.7061%

Figure 2
Sample Factor Value Paths Under WITCH Model Scenarios

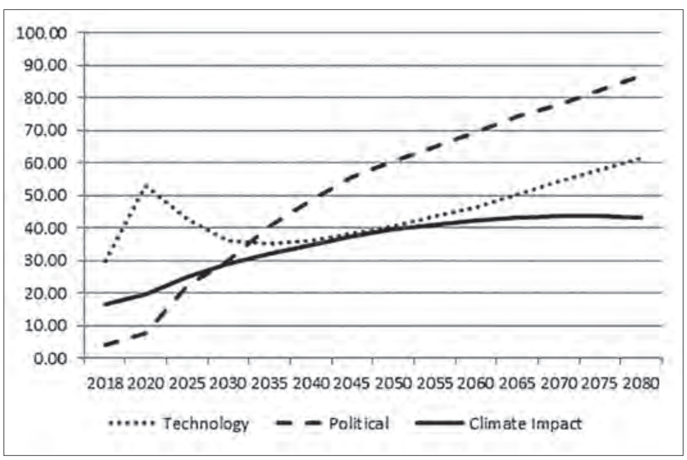
1) Fragmentation (weak pledge)



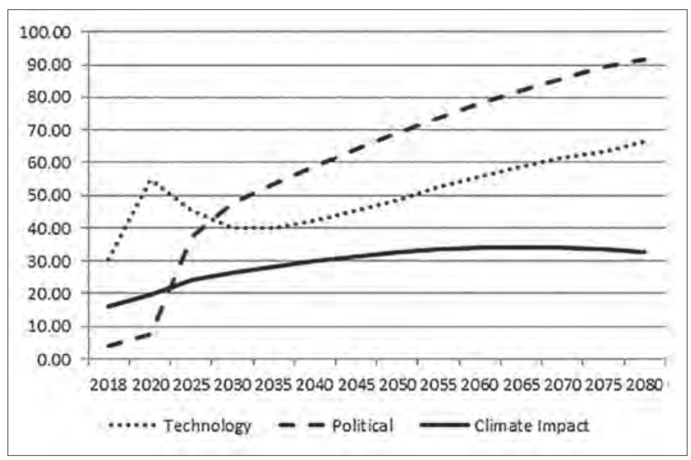
3) Transformation (450 ppm, with permit)



2) Coordination (500 ppm)



4) Transformation (450 ppm, no permit)



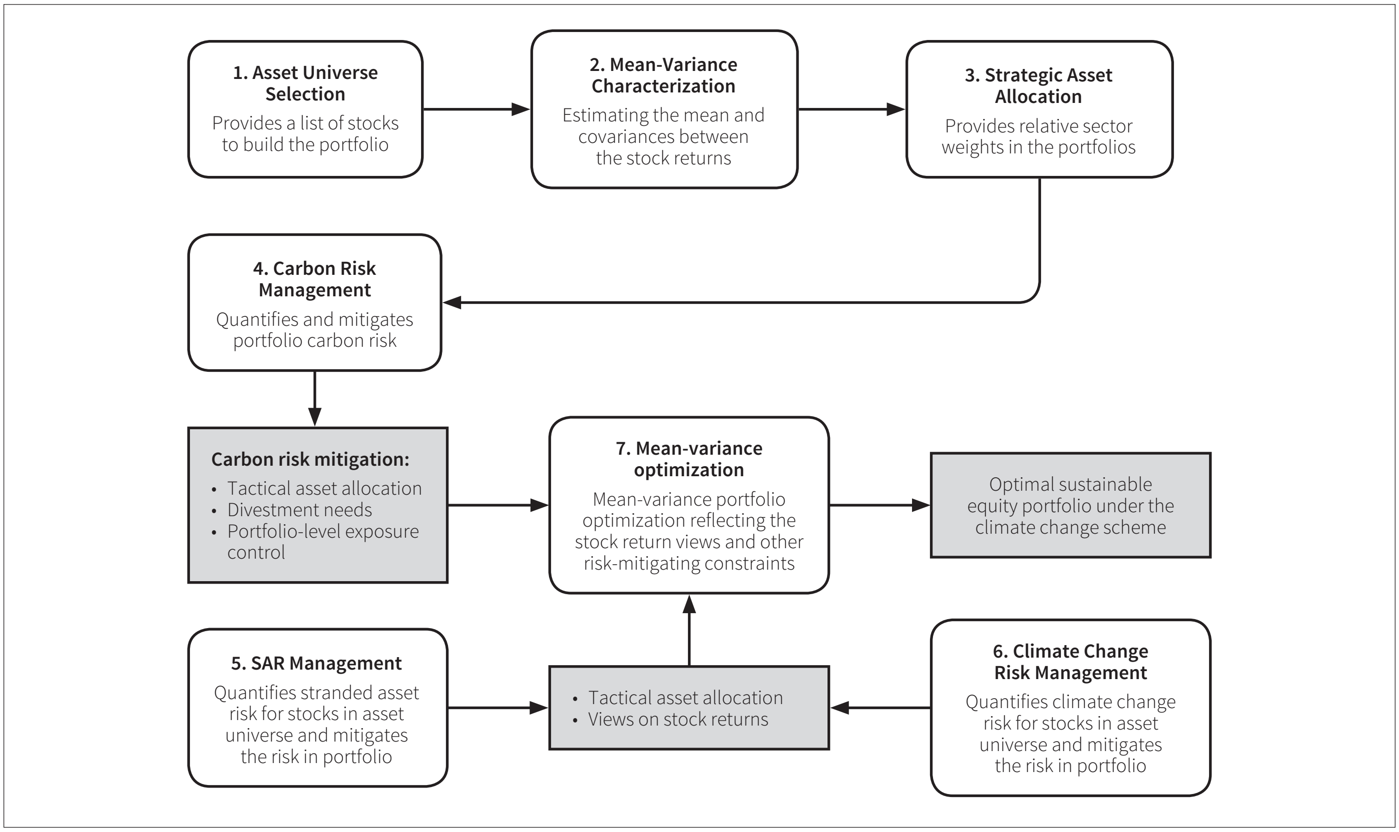
Notice that in the result summary in Table 3, the health care and IT industries are actually expected to benefit from climate change. This is an advantage of the scenario-based approach in which impacts from the risk are assessed fairly by considering both the upside and downside.

THE FINAL CHAPTER: BUILDING A SUSTAINABLE PORTFOLIO

The complete framework for constructing a sustainable portfolio is summarized in Figure 3 (Pg. 22).

The framework assumes the traditional mean-variance approach in a portfolio optimization, where the minimum variance portfolio is desired given a target portfolio return. Modules 1 to 3 are existing components of the algorithm, where a universe of investible stocks is selected with strategic allocations reflecting regulatory constraints and other internal policies or preferences. The mean and covariance matrices of the stocks in the universe are estimated. Without considering sustainability, we have all the inputs to run the optimization after Module 3. This would normally be the end of the story.

Figure 3
Framework for a Sustainable Portfolio

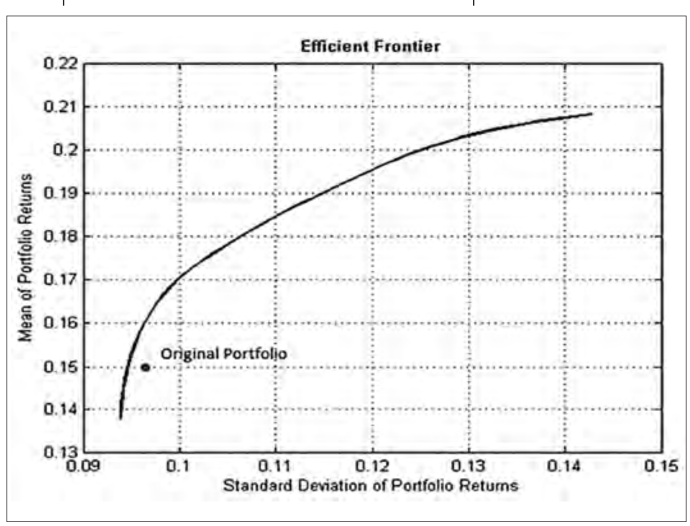


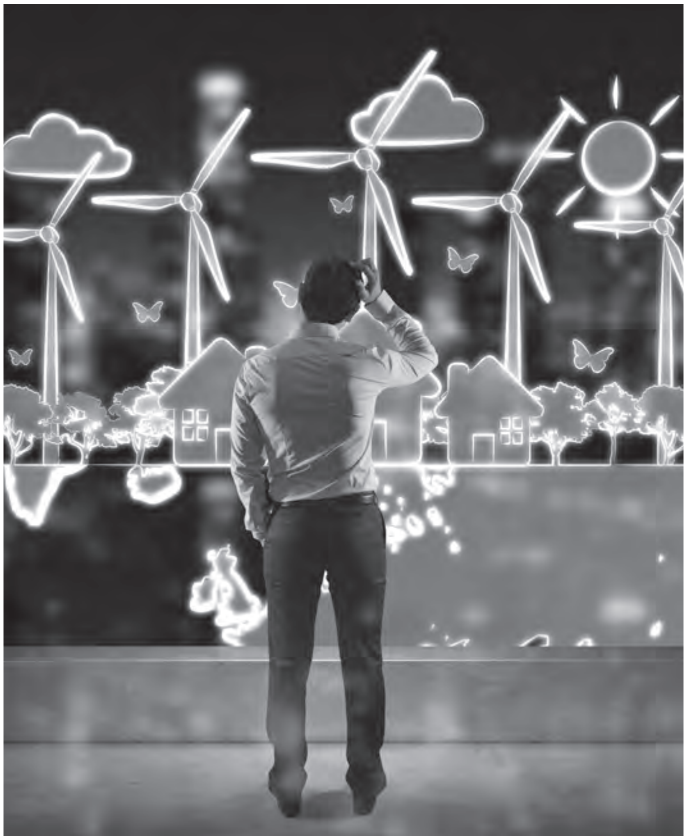
Sustainability concerns under climate change are addressed through modules 4 to 6, where relevant risks are quantified and managed. The key outputs from these modules are:

1. Tactical asset allocations, which adjust the original strategic asset allocations to reduce the various risk exposures at the portfolio level
2. Proper divestments from carbon-intensive industries
3. Imposition of a portfolio-level cap on carbon risk exposure
4. A view matrix for returns of stocks in the asset universe, reflecting their climate change risk exposures estimated using the approach introduced previously

Items 1 to 3 above result in updated constraint equations to the optimization algorithm, while item 4 leads to a new mean return matrix (to avoid complexity, we assume the return covariance structure is not materially impacted by climate change). A mean-variance optimization is finally performed to obtain the weights of the optimal sustainable portfolio. Figure 4 is an excerpt from the illustrative examples in our report showing that the original minimum-variance portfolio (the dot, assuming 15 percent target portfolio return) falls below the efficient frontier when climate change risks are considered.

Figure 4
Sample Efficient Frontier Under the Proposed Framework





CONCLUSION

Optimal sustainable portfolios under the global climate change scheme can be built through a proper quantification and management of the associated risks, led by the investment carbon risk, the stranded asset risk and climate change risk. Overall, for equity portfolios, global climate change is expected to modify the risk-return profiles of many industry sectors in the long term (e.g., the green energy sector vs. the oil producers), rendering existing portfolios "suboptimal." The framework presented in this article is fully flexible and can be added to existing platforms in the insurance and pension industries to enhance various investment and risk management practices. We hope that it invites more attention and inspires more studies in the area of climate change risk as well as sustainable investing, which shall benefit the actuarial profession and other stakeholders as the world is gradually warming. ■

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ENDNOTES

1 Tan, Ken Seng, Tony S. Wirjanto and Mingyu Fang. 2018. "Managing Climate and Carbon Risk in Investment Portfolios." Society of Actuaries. *www.soa.org/Files/resources/research.../managing-climate-carbon-risk.pdf.*

2 In simple words, Sharpe ratio is the ratio of the asset's expected excess return to its return volatility, while Treynor ratio is the ratio of the asset's expected excess return to its beta (i.e., the systematic risk).

3 The CDP voluntary emission reporting database can be accessed at *www.cdp.net/en/climate*.

4 Simulator is publicly accessible at *www.witchmodel.org/simulator/*, where detailed descriptions of the four WITCH model scenarios referred to in Figure 2 are available.