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Prize Winners

The Society of Actuaries (SOA) Climate and Environmental Sustainability Research Committee is pleased to present this essay collection, which focuses on unknown knowns: where we have data, but the future looks different from the past. The authors identify data sets or historical patterns of experience that are not predictive because something has changed, such as a slow trend or a discontinuity. Recognition of this shortcoming is the first step to publicize the issue and update to more realistic assumptions.

What Makes Green Investment a Puzzle?

Sally Shen

Fighting climate change is expensive.[1] However, fiduciary duty[2] requires institutional investors to actively manage their climate risk. Given the nondiversifiable feature of climate risk, insurance products that can protect against climate change do not exist. For institutional investors, a more natural strategy to hedge climate risk is to replace a portion of the investment portfolio with a class of assets that can not only reduce the portfolio's carbon footprint but that also performs well when the climate is bad. As a starting point, institutional investors can hold "green" financial indexes to reduce their carbon exposure. Although it is still a gray area in terms of qualifying a green investment, this paper generally considers all the financial activities that present a positive exposure to green indexes as green investing.

Over the past decade, the green financial market has enjoyed a fast growth rate. According to the latest Bloomberg report, the global green bond market with an annual issuance of less than $1 billion a decade ago has grown to more than $170 billion by the end of 2017. Green bonds are bonds that green companies issue. Most of the institutional investors in developed markets have embraced the concept of Environmental, Social and Governance (ESG) into their investment process. According to the U.S. Forum for Sustainable and Responsible Investment Foundation (SIF)[3] 2018 biennial report, the ESG assets that institutional investors in the U.S. own expanded to $11.6 trillion in 2018, up 44% from $8.1 trillion in 2016.[4]

However, despite the accessibility of the green financial market, the increasing financial risks that may occur due to climate change, and the awareness of the shift toward more stringent climate mitigation policies in many countries, the motivation behind investing in green financial instruments is, at present, more of a moral choice than a speculative opportunity (Riedl and Smeets, 2017). The myth behind the motivation of green investment is mainly driven by a lack of knowledge about the potential impact of climate change on various asset classes. Most investors believe that they cannot use their investment portfolio to improve environmental performance without sacrificing investment rewards (Walley and Whitehead, 1994), especially for short-term investors (Engle et al., 2018). In general, green investing puzzles investors in two ways. First, investors are not convinced that their exposure to green investment can lead to environmental improvement. Second, whether green investing is an efficient way of hedging climate risk is not verified.

To hedge climate risk, investors are confronted with two types of unknowns: (1) unknown knowns where they have data but cannot predict future outcomes and

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1 In order to achieve the 2 degree Celsius threshold suggested by the International Panel on Climate Change (IPCC) and the Paris Agreement, leaders of many nations have taken actions to reduce the greenhouse gas (GHG) emmisions. Effective GHG abatement actions include shifting energy supply from fossil fuels to low-carbon energy, such as wind, nuclear or hydro power and transiting toward energy-efficient vehicles, buildings and industrial equipment. An estimate from McKinsey (Nauclér and Enkvist, 2009) shows that the total upfront investment in abatement required to meet the 2 degree Celsius threshold may be as high as €530 billion in 2020 or €810 per year in 2030.

2 Such as the Task Force on Climate-related Financial Disclosures and the International Panel on Climate Change (IPCC 2014).

3 See Bullard, Nathaniel and Daniel Shurey. How the World's Governments Are Approaching Earth-Friendly Investing. *Bloomberg*, July 24, 2018, *https://www.bloomberg.com/opinion/articles/2018-07-24/green-bonds-could-become-a-key-part-of-global-capital-markets* (accessed March 25, 2019).

4 See U.S. SIF Foundation Releases 2018 Biennial Report on U.S. Sustainable, Responsible and Impact Investing Trends. *The Forum for Sustainable and Responsible Investment*, October 31, 2018, *https://www.ussif.org/blog_home.asp?Display=118* (accessed March 25, 2019).
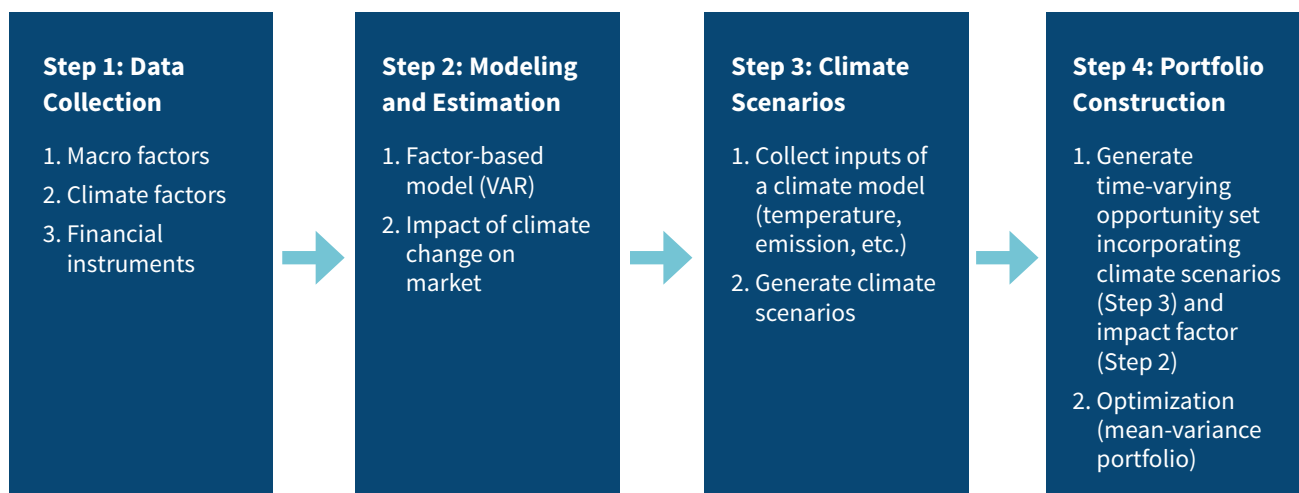
(2) unknown unknowns [5] where they cannot foresee future outcomes. There are two typical unknown knowns that green investors are confronted with. First, the impact of climate change on various asset classes is unclear to most investors. Second, returns of financial instruments are unpredictable, especially those of green assets,[6] due to their short time series of returns.

The second type of unknown—the unpredictability of returns—worries investors most. The main source of unknown unknowns is an unpredictable climate-change trajectory. The projected Earth's surface temperature changes vary between 1.4 to 5.8 degrees Celsius by the end of 21st century (Gitay et al., 2002). The large dispersion reflects the unpredictability of the climate change path. The other challenge is a mismatched and unknown timing between market awareness of the rewards of green investing and the limited investment horizons. Climate risk is an ultra-long (30 years and beyond) term risk. Thus far, temperature change has had minimal influence on the financial market

performance, especially for active managers with short-term investment horizons. Therefore, many fund managers find it risky to replace their portfolio fully with green instruments because of the short-term risk before the possibility of significant gain from their green investment.

This paper develops a four-step approach to help investors address the two layers of unknowns and to find a strategic pathway for green investing (see Figure 1). As a starting point (Step 1 and Step 2), investors can obtain historical information to determine the probability distribution of their investment opportunity set and the likelihood of climate impact on various asset classes. Table 1 presents a snapshot of the climate effect on asset returns, using a factor-based vector autoregression model (VAR). In the VAR model, we use temperature change as an indicator of climate risk. Table 1 shows that green assets are in general resilient against temperature shocks, while many traditional asset classes are negatively related to the risk of global warming.

Figure 1 A Strategic Pathway of Green Investing

Step 1: Data Collection
1. Macro factors
2. Climate factors
3. Financial instruments

Step 2: Modeling and Estimation
1. Factor-based model (VAR)
2. Impact of climate change on market

Step 3: Climate Scenarios
1. Collect inputs of a climate model (temperature, emission, etc.)
2. Generate climate scenarios

Step 4: Portfolio Construction
1. Generate time-varying opportunity set incorporating climate scenarios (Step 3) and impact factor (Step 2)
2. Optimization (mean-variance portfolio)

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5 "Unknown unknown" is a phrase from a response that United States Secretary of Defense Donald Rumsfeld gave to a question at a U.S. Department of Defense news briefing on Feb. 12, 2002, about the lack of evidence linking the Iraq government with the supply of weapons of mass destruction to terrorist groups.

6 This is driven by the fact that the standard error of the historical average return shrinks at the square root of the sample period's time. The longest existing market instrument has a history of no longer than 100 years, and the length of low-carbon indexes is even shorter, with a history of fewer than 10 years.

Table 1 Impact of Instantaneous Temperature Change on Various Asset Classes

Assets	Stocks	10-Year Bonds	Corporate Bonds	Commodity	Real Estates	Hedge	Green Bonds	Green Equity	SRI Index	Clean Tech	Clean Energy
Impact	−0.09*	−0.01	−0.03*	−0.79*	−0.18	−0.14*	−0.21	0.23	0.30*	0.57*	−0.38

We consider five eco-friendly asset classes, including green bonds, green equity, socially responsible funds, clean technology and clean energy funds in addition to stocks, bonds and alternatives. SRI = Socially Responsible Index, Clean Tech = Clean Technology Portfolios.

* = significance level with the p-value less or equal to 0.15.

Source: Author's own calculation based on findings from Shen, S., LaPlante, A., and Rubtsov, A., 2018. Strategic Asset Allocation With Climate Change. *SSRN, https://ssrn.com/abstract=3249211* (accessed March 26, 2019).

In Step 3, investors need to employ climate models to generate future scenarios. Figure 2 plots an example of quantitative climate scenarios using the DICE model. In the last step, investors can project a time-varying investment opportunity set incorporating the estimated climate impacts (Step 2) and future climate scenarios (Step 3), then solving an optimal mean-variance optimization problem to obtain their optimal portfolio.

The four-step approach not only quantifies the historical climate effect on assets but also brings this impact to the unknown future. Shen et al. (2018) show green investing should not be a puzzle if investors consider the dynamic impact of climate change on various assets.

Figure 2 Climate Scenarios Using DICE Model
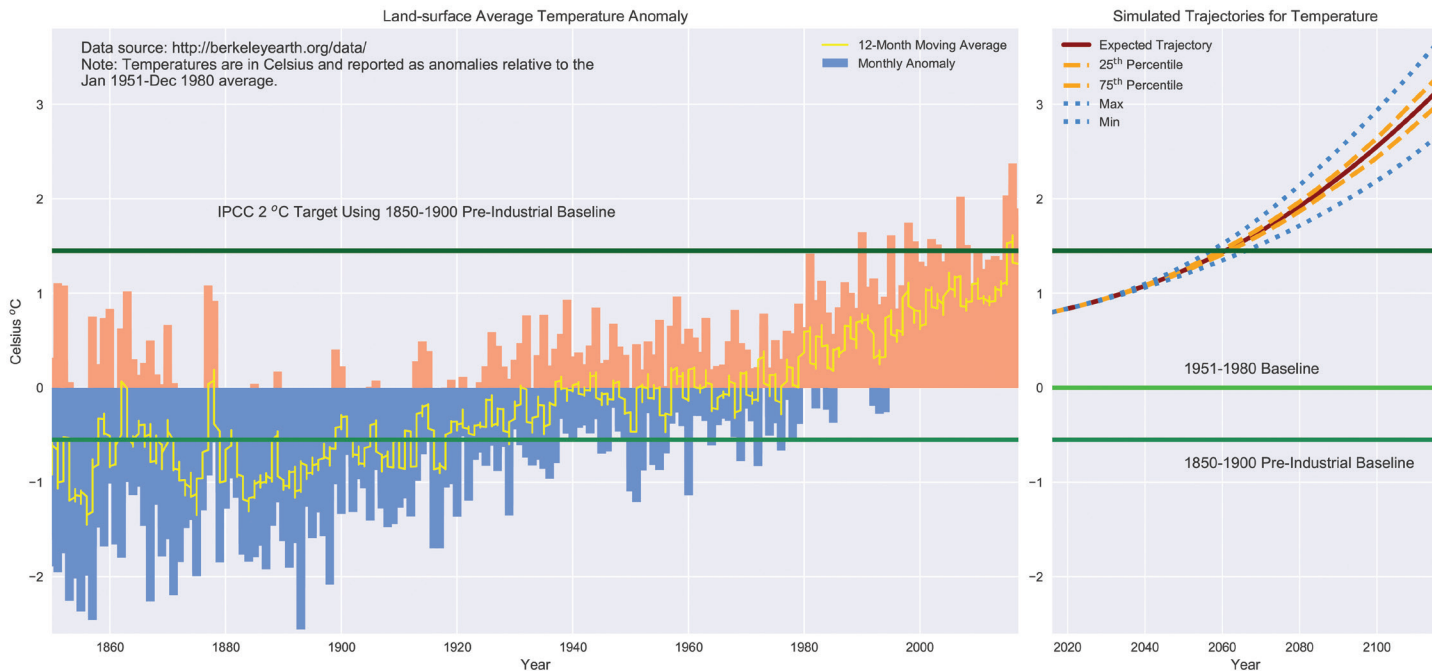
Source: Author's own simulation and plotting.

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Unknown Knowns: Time Horizon

Max J. Rudolph

The world is changing faster than ever. We have gone from console TVs to 100-inch screens and made the world healthier by spreading sanitation infrastructure and vaccines. We have modified genes and shrunk the world by making long-distance travel and communication easy. Nevertheless, not all changes have been positive. Drugs and alcohol shorten life expectancy, poor diets and lack of exercise lead to high obesity levels, and regulatory capture allows bankers to pass losses onto taxpayers.

This has created a new world, but we still design products for the old one. We assume event independence when clustering is a major insolvency risk. We should be building products that will be attractive in 2050. How did we get here?

Actuaries love data. The more the better, and the law of large numbers is our sweet spot. But many products sold today take risks that do not obey this law. Systemic risks are accepted without being recognized or understood. We are at our best when pricing offsetting risks. Give us 1,000 people aged 80 and we can come pretty close to telling you how many will be alive in a year. That is our wheelhouse. However, we wrote products that assume equity risk diversifies, that families would always struggle over the decision to put loved ones in a nursing home, that opioids would be used responsibly and not become addictive, and that gun laws would avoid the resulting carnage. We assumed pension funding could eliminate the funding shortfalls even though a plan life cycle lasts longer than funding entities.

We have ignored changes in climate while biodiversity disappears all around us. Historically, even short warming cycles have resulted in disease outbreaks, and the world is warming at an accelerating pace. What tipping points await us? How will any of us survive a major war fought with fossil fuels that belch carbon into the atmosphere with abandon?

Investment returns have been subsidized for so long that the key driver for models is now the chairman/chairwoman of the Federal Reserve. Fiscal policy is loose. Monetary policy is loose. Russia, China and India are accumulating gold. U.S. actions threaten its status as the world's reserve currency. Many are using the resulting low rates to add leverage. Inexplicably, few seem to worry about this or alter their pricing. Cat bonds, which require investors to buy the risks you can't manage, are not always a solution. Everything is changing. (Thank goodness for Max Roser and Hans Rosling reminding us that many trends have been positive, especially in developing regions.)

Mortality trends transition along with changes to what we put in our bodies, and there is no sign of a reversal to head off diabetes and substance abuse epidemics. The days of mortality improvements that could be priced into a life insurance product are gone. Add this to potential pandemics and weakening antibiotic success rates, and maybe pension plans and Social Security are really not underfunded after all.

Writing insurance products with 50-year time horizons used to be effective but not anymore. Insurers accept risks that may last for a century. What was life like in 1919? Would we recognize it? What makes us think 2119 will be any more familiar to us? We have lots of data from the past century. How much of this data will be useful to price risks in the next century? The faster things change, the shorter insurance guarantees need to be. Products should avoid systemic risks that do not balance out, and sometimes reinforce each other, and focus on short-term offsetting risks that allow frequent repricing. If you are not sure whether a prior risk is predictive of the future, graph it. Hope for linear trends, and beware of any curves warning you of higher order interactions unless they appear to be random noise around a steady signal.

What is the one assumption that you should revisit? While also focusing on demographics and risks that diversify in aggregate using the law of large numbers, time horizon should be the focus. Artificial intelligence and predictive analytics are important, but they both

assume that historical data are predictive for the future. They are not. Our job as actuaries is going to get a lot harder, and we need to start building the tool kit and thought process now to meet those needs. We like to drive using the rear-view mirror, but there are curves and cliffs all along our route. We must peer around the bend!

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