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CLIMATE RISK IN PORTFOLIOS: WHAT IS GOING ON?

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There is a surprising amount of dispute over some obviously indisputable facts: atmospheric CO_2 levels, sea levels and global average temperatures are all rising significantly. For 60 years, the observatory at the top of Mauna Loa (a volcano in Hawaii) has recorded the proportion of CO_2 in the earth's atmosphere. It is a seasonal and moderately volatile series, rising by approximately 0.6%/yr; a rate which has doubled over the last 60 years.[1]

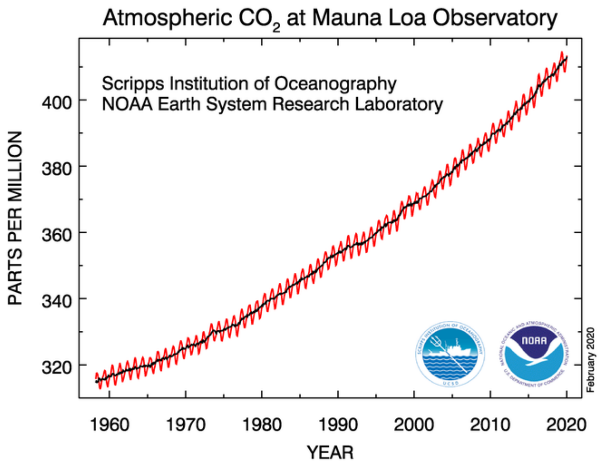

Fig.1 Atmospheric CO_2 at Mauna Loa Observatory.
Source: https://www.esrl.noaa.gov/gmd/ccgg/trends/mlo.html

Ice cores drilled in Antarctica allow us to measure the level of CO_2 and corresponding temperature levels for the last 800,000 years.[2] This data comes with a lag as it requires air bubbles to be trapped as snow turns into ice (about 90m below the surface). Current readings from Mauna Loa would be materially higher than the upper scale of this chart.

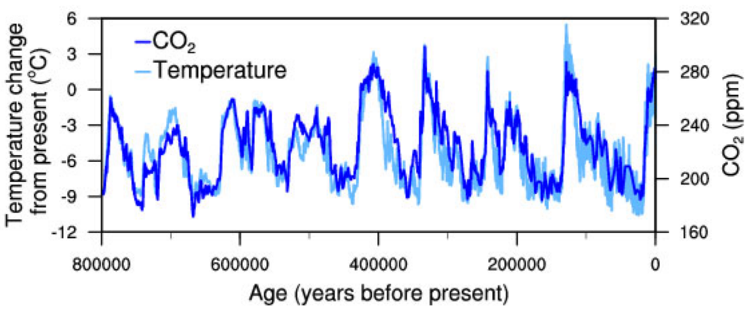

Fig. 2: Temperature Change and Carbon Dioxide Change.
Source: https://www.ncdc.noaa.gov/global-warming/temperature-change

[1] *https://www.esrl.noaa.gov/gmd/ccgg/trends/gr.html; https://www.esrl.noaa.gov/gmd/ccgg/trends/mlo.html*
[2] *https://www.ncdc.noaa.gov/global-warming/temperature-change*

We can also be certain that sea levels are rising.[3] The chart below shows global average sea levels since 1900. Before 1993, there is a reliance on aggregating historic point measurements, hence the wide uncertainty bands. Since 1993, satellite altimetry has provided global wide, accurate data. (Large volcanic eruptions are highlighted as these temporarily lower temperatures, and sea surface levels, as stratospheric sulphur aerosols scatter and reflect solar radiation). Sea surface change is not universally constant: sea levels in New York are rising at twice the global average rate, meanwhile in the UK, sea levels are rising faster in England than in Scotland (as Scotland is rebounding having been depressed beneath ice coverage in the last glaciation).

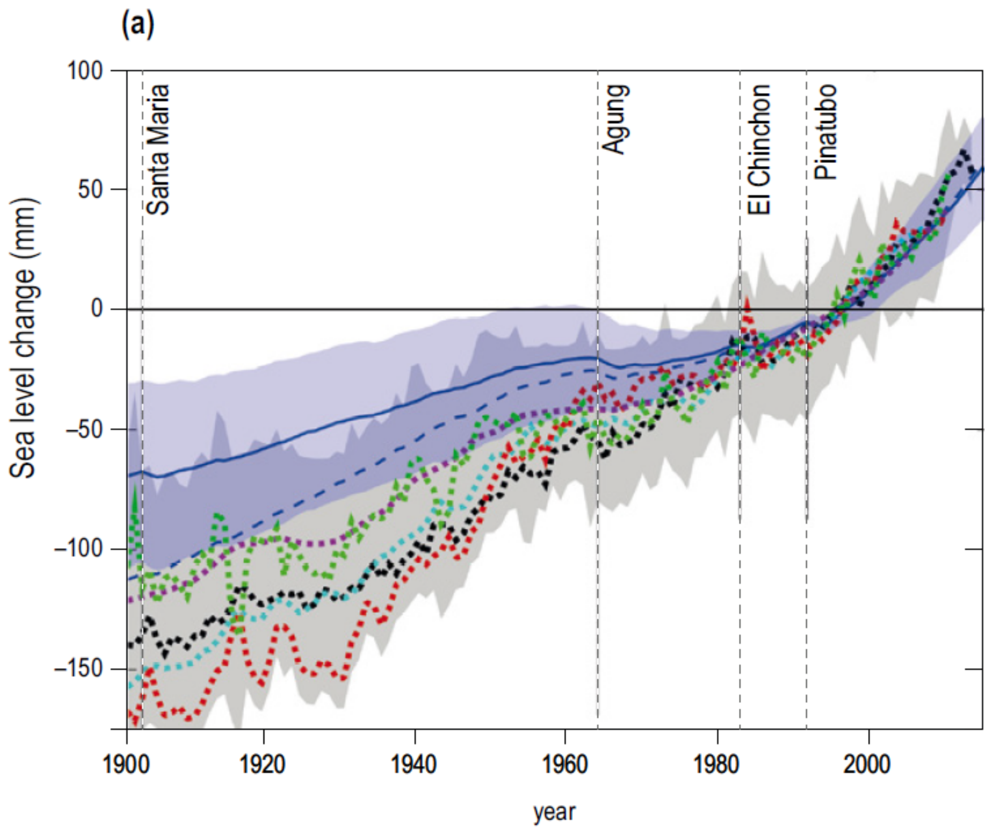

Fig 3. Global average sea levels since 1900.

Source: https://www.ipcc.ch/site/assets/uploads/sites/3/2019/11/08_SROCC_Ch04_FINAL.pdf

Measuring surface temperatures is far more complex than measuring CO_2 or surface levels: you are aggregating annual and diurnal ranges across hugely diverse environments, above land and sea. You also need to incorporate sea surface temperatures themselves. Although we focus upon climate impact, the overwhelming majority of this additional heat energy has been absorbed by the oceans; without which, atmospheric temperatures would have risen by 36°C rather than 1°C over the last 150 years.[4]

[3] *https://www.ipcc.ch/site/assets/uploads/sites/3/2019/11/08_SROCC_Ch04_FINAL.pdf*
[4] *https://www.imperial.ac.uk/media/imperial-college/grantham-institute/public/publications/briefing-papers/Ocean-heat-uptake---Grantham-BP-15.pdf*

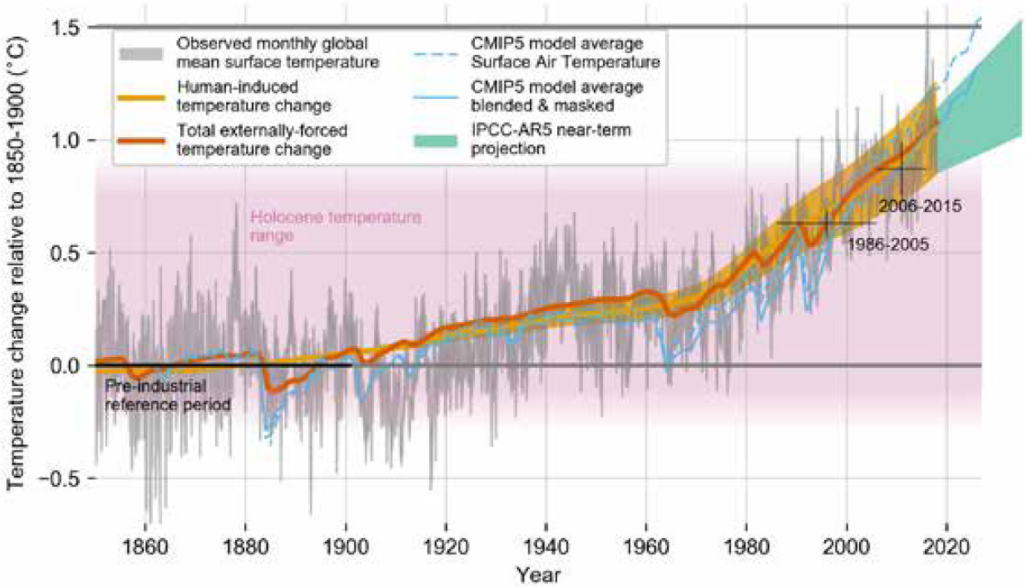

Fig. 4: Evolution of global mean surface temperature (GMST) over the period of instrumental observations.

Grey shaded line shows monthly mean GMST in the HadCRUT4, NOAAGlobalTemp, GISTEMP and Cowtan-Way datasets, expressed as departures from 1850–1900, with varying grey line thickness indicating inter-dataset range. All observational datasets shown represent GMST as a weighted average of near surface air temperature over land and sea surface temperature over oceans. Human induced (yellow) and total (human- and naturally-forced, orange) contributions to these GMST changes are shown calculated following Otto et al. (2015) and Haustein et al. (2017). Fractional uncertainty in the level of human-induced warming in 2017 is set equal to ±20% based on multiple lines of evidence. Thin blue lines show the modelled global mean surface air temperature (dashed) and blended surface air and sea surface temperature accounting for observational coverage (solid) from the CMIP5 historical ensemble average extended with RCP8.5 forcing (Cowtan et al., 2015; Richardson et al., 2018). The pink shading indicates a range for temperature fluctuations over the Holocene (Marcott et al., 2013). Light green plume shows the AR5 prediction for average GMST over 2016–2035 (Kirtman et al., 2013).

Source : https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_Chapter1_Low_Res.pdf

Prof Myles Allen from Oxford University's Environmental Change Institute led the IPCC effort to disentangle all of the factors at work driving changing temperatures.[5] The yellow line above shows the modelled estimate for human induced change; the differences between the dark orange line and the yellow line are non-human factors; the grey bars are actual observations.

We are now able to disprove all sorts of possible explanations for what is going on in the earth's atmosphere. We have satellites measuring how much solar radiation reaches the earth; we have measurement stations measuring how much reaches the earth's surface; we then have more satellites measuring how much energy is reflected back into space. We can also measure the wavelengths at which that energy is exiting the earth's atmosphere (i.e. identify what is trapping the energy). Increased CO_2 traps heat; the warmer atmosphere can hold more water vapour, which traps yet more heat. There are other factors at play, but overwhelmingly it is human activity that has increased CO_2 levels, which increased global temperatures.

The last point I would make is that this is an extraordinarily complex system. The "Younger Dryas" event provides a superb illustration: about 12,000 years ago, the world's finest

[5] *https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_Chapter1_Low_Res.pdf*

climate scientists would have concluded that shifts in the earth's orbit were increasing the amount of solar irradiation reaching the earth. This made significant global warming inevitable. Global temperatures rose by 4-8°C… and then promptly crashed back down to levels even lower than beforehand. In Canada, the higher temperatures had caused a significant amount of ice to melt, becoming trapped in huge lakes behind glaciers. As the temperatures rose, the glaciers failed and a vast quantity of near freezing fresh water skittered across the surface of the North Atlantic. This caused a near-instantaneous drop in temperatures in Europe, and a slightly slower impact across the Northern Hemisphere as the thermohaline circulation (hugely powerful ocean currents redistributing heat and salt levels around the planet) was impaired. It took almost 1,000 years for this effect to wash out, before surface temperatures shot back up to new highs. Throughout this time, the earth (as a whole) was getting warmer… it is simply that a lot of heat had been gained in the cryosphere, with a corresponding, smaller amount lost in atmospheric systems.

Understanding climate change has to be done on a global scale considering aggregate heat energy in the atmosphere, oceans and cryosphere.

Long-term consequences

This chart is probably the most important thing to understand in climate science. First, for the last 10,000 years (the entirety of modern human history) environmental conditions have been very stable. As we move back in time, we have less frequent data points (a lot can happen in a million years) and greater uncertainty interpreting the available data.

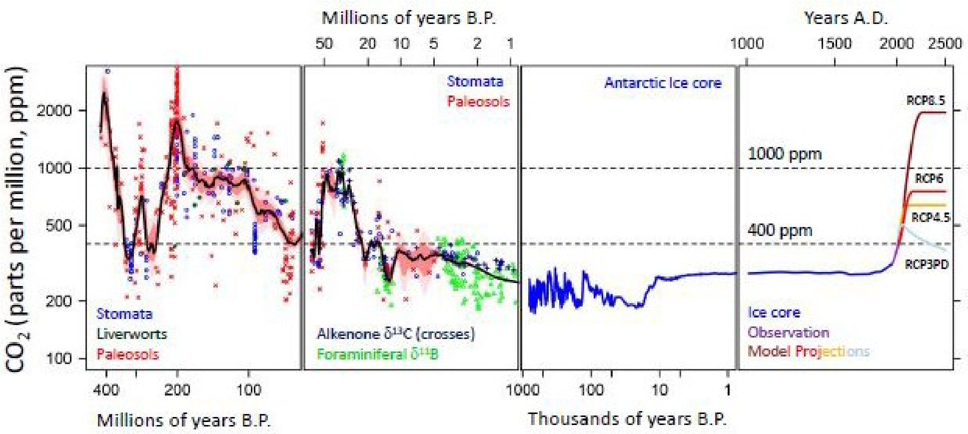

Fig.5: CO_2 levels over the last 400 million years.

Source: https://e360.yale.edu/features/how-the-world-passed-a-carbon-threshold-400ppm-and-why-it-matters

The two horizontal lines are paramount: 400ppm is roughly where we are today (so very different from human history). 1000ppm is a sensible estimate of the point at which we potentially threaten the viability of life on earth. 250 million years ago, global CO_2 levels rose from levels roughly similar to today: for 50-100,000 years, ~0.2-0.4Gt/yr of CO_2 was injected into the atmosphere (theories vary between large coal beds burning on top of a Siberian volcano to evolution of fungi that could digest woody vegetation[6]).

[6] *https://science.sciencemag.org/content/336/6089/1715*

At some point during this time, insects (which are less efficient at respiration) reached a tipping point: the oxygen levels were insufficient to support them, and they were wiped out. With the insects went the food chains around them. Meanwhile, the earth's oceans were steadily acidified by the more carbon rich atmosphere… having a similar effect on plankton. This "Permian Mass Extinction" saw more than 90% of life on earth wiped out. It was almost certainly caused by increased CO_2 in the atmosphere. Another, less severe, mass extinction event occurred ~35m years ago, similarly coincident with CO_2 reaching ~1,000ppm.

Today, we are belching out CO_2 at a rate of ~40Gt/yr, more than 100x faster than during these mass extinctions. We don't know at what level we cause widespread ecological distress… at some point before 1000ppm seems a sensible working assumption. To be clear, many environmental campaigners risk overstating the short-term impacts, but the long-term consequences of our current trajectory are catastrophic.

At the current rate of emissions, that gives us about 200 years: a sobering thought for a business that recently celebrated its own 200th anniversary. The effects of this are already happening. Half of the Great Barrier Reef is now dead, due principally to higher sea surface temperatures.[7] Reefs contain roughly 25% of known marine life.[8] The more severe impacts of rising carbonic acid in sea-water impacting zooplankton shell formation, or of oxygen deprivation on much marine life, have yet to occur.

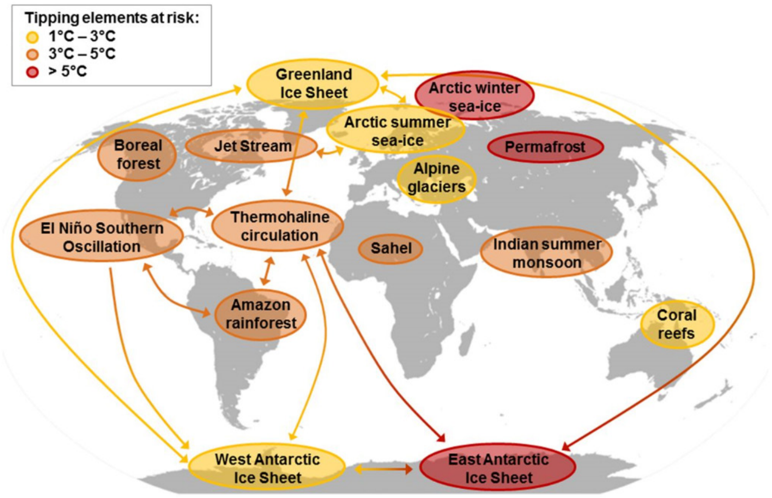

Fig. 6: Global map of potential tipping cascades.

Source: https://www.pnas.org/content/115/33/8252

Having said that near term risks are over-stated, there are some medium term tail-risks which could curtail our 200-year window based on current emission levels.[9] Atmospheric physics interacts with an array of other systems in complex fashions, which could form accelerating feedback loops. For example, warming leads to melting permafrost, releasing CO_2 from currently frozen organic matter. Additionally, warming causes the Greenland ice sheet to melt, exposing the underlying ground.

[7] *https://www.nationalgeographic.co.uk/environment/2018/08/half-great-barrier-reef-dead*
[8] *https://www.fisheries.noaa.gov/national/habitat-conservation/shallow-coral-reef-habitat*
[9] *https://www.pnas.org/content/115/33/8252*

The exposed ground has lower albedo (reflects less sunlight) so warms up more than the ice, further accelerating the rate of glacier retreat. If you release the Greenland ice sheet into the Atlantic Ocean, sea levels would rise by 6m[10] and you will very probably impair thermohaline circulation, impacting local climate conditions everywhere.

Unfortunately, our understanding of the mechanics of glacier behaviour under different temperature scenarios is not great. The speed with which this might happen, or the temperature at which it happens, is unknown… and if you really want scare yourself, the same effect from the Antarctic ice sheet would raise sea levels by 60m.

This is not a defeatist's charter, but a clear message that to ensure that my children can look forward to their grandchildren enjoying long and happy lives, we need to take significant action in the coming decade or so. The longer we leave it, the bigger the problem we will leave ourselves, the less time to address it and the greater the risk that we trigger an unpleasant feedback loop to compound the problems.

Short-term consequences

It is inevitable that our impact upon the climate is going to increase in coming years. The negative effects of CO_2 on the climate are cumulative. Unless we are producing less CO_2 than the environment naturally sequesters, we will be increasing atmospheric CO_2 loadings and increasing temperatures (albeit more slowly). Even the most optimistic targets have us aiming to limit warming to 1.5°, which will likely have widespread and significant impacts.[11]

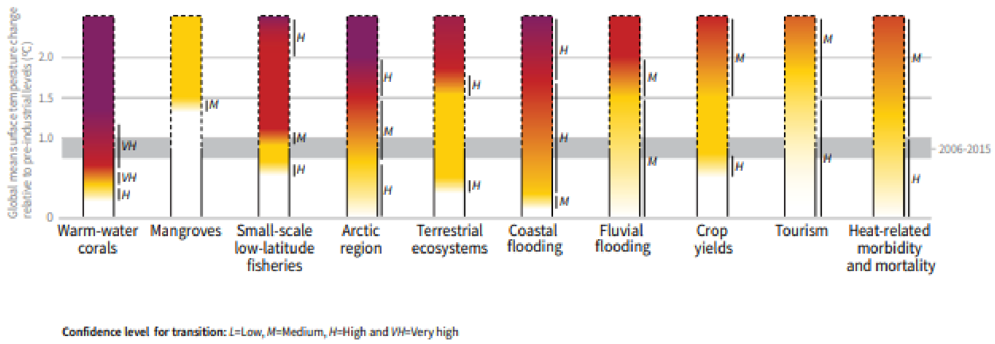

Fig. 7: Impacts and risks for selection natural, managed and human systems

Source: https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_LR.pdf

The easiest impact to predict is thermal expansion of water. As the oceans warm up, water expands; the ocean has nowhere to go except up: sea levels rise. Sea levels in southern Britain are projected to rise at ~10cm/decade[12]. The sea moving half a meter up the beach is unlikely to have much impact in itself, but it means that naturally occurring extreme events become more frequent. A one in 100 year event becomes a one in 20 year event. Vulnerable coastal property becomes uninsurable and functionally worthless.

[10] *https://nsidc.org/cryosphere/quickfacts/icesheets.html*
[11] *https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_LR.pdf*
[12] *https://www.theccc.org.uk/wp-content/uploads/2015/10/CCRA-Future-Flooding-Main-Report-Final-06Oct2015.pdf.pdf*

There is a more insidious threat to low lying areas: salt water intrusion. As sea-levels rise, the water table shifts; more specifically, the boundary between fresh water aquifers and salt-water or brackish water migrates inland. Previously fresh water wells become contaminated with salt water, with catastrophic consequences for local populations. We also need to be aware that changing temperatures and chemistry in the oceans will affect marine life populations and fishing yields. IPCC forecasts on this front are deeply troubling.[13]

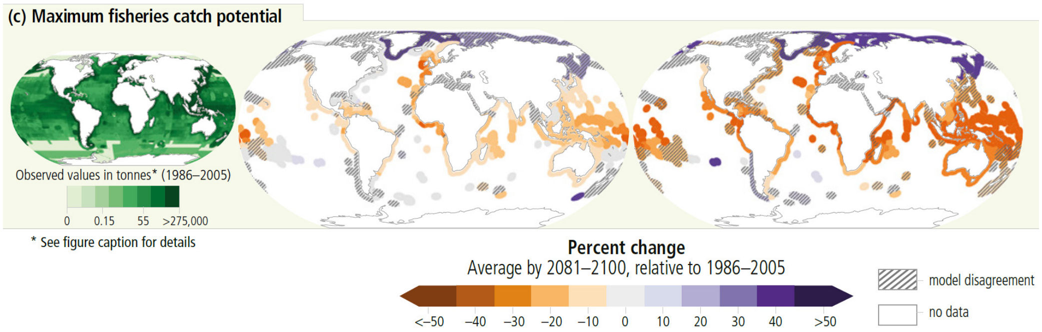

Fig. 8: Projected changes, impacts and risks for ocean ecosystems as a result of climate change

Source: https://www.ipcc.ch/site/assets/uploads/sites/3/2019/11/03_SROCC_SPM_FINAL.pdf

The impacts of global climate change on local weather, temperature and rainfall are far more complex. Accurate regional scale climate projections are very much a work in progress and attribution of recent events to climate change (although appealing) must be done with caution. Has global warming had a role in the recent Australian bushfires? Quite probably, by shifting the background environment to make them more severe should they occur. However, in the short term, the confluence of sea surface temperature fluctuations and "normal" weather variations meant this year was going to be bad for bush fires regardless. Has it had an influence on the current floods in the UK? A warmer, wetter atmosphere will transport more water; but, in the short term, it is the alignment of the jet stream that is dumping huge quantities of rain onto uplands in Wales. Climate change will make these events more frequent and more severe when they do occur, but will not "make them happen".

As a rule of thumb, we should expect existing circulatory patterns to become more intense. As equatorial regions become hotter, the engine room of global climate will see warm air rise more powerfully, holding more moisture. As this moisture cools, it will in most cases result in more local rainfall. As this rising air is then driven away from the equator it will cool and begin to sink. This sinking air will get warmer, able to hold more moisture and so the land below more arid. It is possible that these arid regions (like the Sahara) shift or expand. This more powerful circulation will have knock-on effects into mid-latitudes, whilst higher sea surface temperatures will also increase the energy in local weather systems and the warmer air will be able to hold more moisture: it becomes stormier and wetter.

What should we do about it?

Climate change has become a popular theme in the investment world. As with all popular themes, this raises significant risk from misallocation of capital by jumping on one

[13] *https://www.ipcc.ch/site/assets/uploads/sites/3/2019/11/03_SROCC_SPM_FINAL.pdf*

bandwagon or another. Just because a business has something to do with water supplies, alternative power generation or has a low carbon footprint, does not make it a good investment. As is usually the case, it is easier to identify a mis-priced risk than a mis-priced opportunity, particularly as the latter requires an increasingly uncertain and unpredictable world to turn out as you hope.

1. Avoid mispriced physical risk

Active portfolio managers are able to identify which of their businesses are exposed to obvious problems. Manufacturing facilities in low-lying coastal locations or in locations vulnerable to extreme weather events are a bad idea. Similarly, owning that real estate is even worse. Early engagement with management teams to identify these risks and take mitigating action is one of the most effective steps we can take. An orderly relocation (which can be managed over the next several years with minimal disruption) is far preferable to a panicked attempt to shift production from a flooded site.

Some business models will become far more difficult to forecast and value. Energy supply and trading is dependent upon assumptions about seasonal temperatures (driving gas demand and pricing); property insurance is dependent upon assumptions about the frequency of extreme weather events. Both must be more uncertain over the next decade or two than the last, meaning their cost of capital is likely to rise and their reliability of returns decline: an unhelpful backdrop to any investment case.

One of the challenges to finding a solution to climate change is the extent to which different regions are affected differently. Portfolio managers need to be aware of which regions of the world will be more or less vulnerable to change. Increasing environmental stress is unlikely to be conducive to robust growth rates and healthy economies, particularly if those economies are dependent upon primary industry (especially agriculture). Lower and more volatile growth will likely raise the cost of capital and lower returns on capital.

Unfortunately, this increased environmental stress will probably increase social frictions. Robust political, financial and legal systems will be essential for economies to cope with these challenges effectively. Portfolio managers will need to start looking at risk in their portfolios through an array of different lenses, over different time frames, using different tools.

2. Avoid mispriced transitional risk

Hopefully, it is reasonably obvious that a course of action which risks such catastrophic environmental outcomes is going to see political action at some point sooner rather than later to transition to a more environmentally sustainable path. As the base level of atmospheric CO_2 is so much higher than 20 years ago, and the rate at which we are injecting CO_2 into the atmosphere so much faster, so the rate at which we should expect to see growing negative impacts should accelerate incoming years, likely adding a greater sense of urgency.

At some point within a pension fund's investment horizon, the global economy will have to shift to net zero or less CO_2 emissions. Investments in industries with large carbon footprints are exposing the investor to significant levels of uncertainty and risk. You know that the business is going to have to change its model: either it will need to reposition into a new activity, or it will have to innovate and invest to deliver its existing activity with less environmental impact. Both of these alternatives are riddled with uncertainties: is it technically possible, will it be equally profitable, how much cash flow will need to be diverted to achieve this, how painful will the transition period be? In the meantime, investors will become increasingly wary of the unsustainable nature of existing activities and quite possibly concerned about the threats of litigation or punitive taxation treatment. An investment today would have to offer overwhelmingly attractive short-run returns to offset these risks. Commodity activities are particularly vulnerable as the backdrop will likely be one in which carbon intensive commodities are receiving pricing signals to reduce supply; which means there will be little cash generation to support the migration to new technologies or activities.

3. Prepare for uncertainty

The precise environmental impacts are very difficult to forecast; the combination of environmental impact, consumer attitudes and political mitigation strategies and their combined impact upon investment out-turns are entirely unforecastable. Businesses and investments must be resilient to change and flexible to adapt, with management teams that are alert and responsive.

Resilience and flexibility will be the two most important characteristics of successful investment in an era of accelerating climate change. Businesses with large fixed asset bases are fundamentally vulnerable. Physical infrastructure in the wrong location, or the wrong activity, can be materially impaired. Businesses reliant on assets with long lives may struggle to generate the cash flows to reposition and may be reluctant to change in their attempts to maintain existing asset values. Heavy debt burdens become particularly dangerous as their first calls on cashflow impair broader flexibility.

The complexity of the environmental challenge means that investors will be dependent upon the expertise of company management teams to manage risks effectively. Management teams that are alert to the threats and opportunities and able to respond swiftly and effectively will be invaluable.

Concluding thoughts

Portfolio managers who have taken time to understand the science and the risks it represents and to think about the exposures this implies for their portfolios have an opportunity to avoid a wide array of risks currently not priced by markets. Those managers who can go a step further and identify risks with their company management teams, engage to encourage early preventative action and to promote the importance of business resilience and management alertness will transform the long-term outcomes for their investors. Rushing out to buy an unproven battery technology probably will not.

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- Degree in Geography from Oxford University.

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