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The Role of Climate Change Scenarios In Investment Portfolios

24 JUNE 2021

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Executive Summary

- For long-term investors like GIC, climate change is a key concern given its imminent impact on the value of physical assets and companies over time. Hence factoring this into both our top-down and bottom-up processes is vital to ensuring a resilient portfolio.
- At the top-down level, GIC partnered with Ortec Finance and their strategic partner Cambridge Econometrics to quantify how long-term capital market assumptions are affected by climate change drivers by stress testing the portfolio against different climate change scenarios. This highlights areas where there are heightened risks, and focuses our efforts on deeper analysis and mitigating strategies to make our portfolio more climate resilient.
- In this report, the main climate change related risks outlined are: (i) timing of climate policies (late, delayed or none), (ii) extent of physical risks (based on a best-case 1.5ºC scenario under Paris Orderly Transition, or a worst-case close to 4ºC scenario under Failed Transition), (iii) how markets price in future climate change risks (smoothly over time or disruptively with a sentiment shock). The three scenarios used are: (i) Paris Orderly Transition; (ii) Delayed Disorderly Transition; (iii) Failed Transition.
- Our analysis shows that climate change-related risks have a negative long-term impact on global GDP and inflation as compared to a climate uninformed baseline, due mainly to physical risks. In contrast, transition risk impacts are net positive as policy responses such as the carbon taxes collected are used to reduce income taxes and increase subsidies for clean energy, resulting in a net fiscal stimulus, while low carbon investments boost aggregate demand. However, there is a wide dispersion of growth impacts across countries and sectors, varying across different scenarios.

> “… Long-term investors may be surprised by the underperformance of the portfolio relative to their expectations, and should be prepared to navigate the potential increase in market volatility as a result of climate-related shocks.

- Risk assets like equities and real estate are more sensitive to climate change compared to bonds and cash, though equity markets with very low exposures to low carbon electric utilities (e.g. emerging markets) have more potential to outperform in the transition scenarios due to larger room for the sector to grow.
- Based on a hypothetical global 60% equities/40% bonds portfolio, projected returns may still be positive in the long run with climate change, but they are meaningfully lower in our three risk scenarios versus a baseline that assumes no further climate related impacts beyond what has already occurred. Long-term investors may be surprised by the underperformance of the portfolio relative to their expectations, and should be prepared to navigate the potential increase in market volatility as a result of climate-related shocks.
- Hence, while climate change scenario analysis requires various assumptions and results in a wide dispersion of outcomes, it is still good discipline for investors to be prepared and undertake such an exercise.
- Given GIC's long-term mandate, it is essential to prepare our portfolio for such risks. Climate change scenario analysis plays a central role in this via top-down strategic asset allocation, stress-testing and risk management, and the bottom-up integration of scenario inputs and outputs into our active investment processes.

Introduction – The Growing Importance of Climate Change Scenario Analysis

The global community has generally reached a consensus on the inevitability and repercussions of climate change on financial materiality. This is an important milestone for corporates and investors alike, because the focus can now turn to analyzing and addressing this transformational challenge[1].

1 It is one of the most important issues highlighted by global investors in a recent World Economic Forum White Paper on “Transformational Investment: Converting Global Systemic Risks into Sustainable Returns”.

Following from an earlier article on "Why climate change matters for investors", this paper looks at scenario analysis as one of the approaches to measure climate change-related impact on the investment portfolio. It outlines the methodology we have adopted for a top-down estimation of climate change-related impacts on macroeconomic growth and inflation, broad asset class returns, and a representative global portfolio. We also developed three climate change scenarios which we believe are a useful reference set for investors and their portfolios. Finally, we suggest some ways climate change scenario analysis can be integrated into the investment process.

Climate change affects investment portfolios through three channels - physical risks, transition risks and market risks - that are expected to play out over the long-term (see Figure 1).

Figure 1: The Three Channels of Climate Change Impact on Financial Assets

1. Physical Risks	Acute	Impact of extreme weather events like flooding, wildfires, hurricanes, typhoons on direct asset damages, business disruptions, long-term insurability of assets and viability of local activities
	Chronic	Impact of rising temperatures on labour and agricultural productivity; Impact from heat/water stress on business operations
2. Transition Risks	Policy	Impact of policy shifts including carbon pricing, coal phase-out, EV/Transport Policy, fuel subsidies, energy efficiency program
	Technology	Impact from disruptive technologies such as renewable energy, green hydrogen, electric vehicles, mobility, battery and CCS
3. Market Risks	Pricing-In	When, and how much and over what time period markets will price in future climate change-related impacts (physical & transition)
	Sentiment Shock	Whether markets will over-react to climate change-related shocks (e.g. extreme weather events or sudden policy changes)

Source: GIC, Ortec

While understanding the three impact channels is straightforward qualitatively, articulating the transmission pathways and quantifying their impact on financial assets is more complex. The impact of each climate risk factor is highly uncertain in terms of its magnitude, timing and variability across geographies, sectors and asset classes. **For long-term investors, scenario analysis provides a systematic framework for navigating this uncertainty.**

In addition, there is growing pressure on asset owners and managers to conduct such analyses. The Taskforce for Climate-Related Financial Disclosures[2] (TCFD) requires its signatories to assess their portfolios' performance in a 1.5ºC world. The Network for Greening the Financial System[3] (NGFS), central banks and other financial sector authorities[4] are also increasing scrutiny on financial institutions' climate risk exposures and the implications for financial stability, with disclosures set to become more mandatory over the next few years.

Challenges of Undertaking Climate Scenarios for Financial Analysis

While investors are used to conducting scenario analysis and stress testing in their asset allocation and risk management processes, undertaking such an endeavor for climate change is particularly problematic[5]. Models looking at how climate change drivers affect financial variables are still in very early stages of development. To do this effectively, investors need financial models that are:

1. **Comprehensive** - Models need to assess impact not only for the major asset classes including private assets for effective strategic asset allocation, but also for individual securities as each asset is affected by climate change-related factors differently and at different times depending on their geographic and sector exposures.

2 The TCFD was established by the Financial Stability Board (FSB) to develop recommendations for more effective climate-related disclosures. The FSB comprises senior policy makers for the G20 countries, Hong Kong, Singapore, Spain and Switzerland, and regional bodies like the European Central Bank and European Commission.

3 The NGFS is a group of over 90 Central Banks and Supervisors that share best practices and contribute to the development of environment and climate risk management in the financial sector.

4 Since September 2020, regulators in the UK, New Zealand and Switzerland have announced plans to make climate-related disclosures mandatory over the next few years, with stock exchanges in Hong Kong, London and South Korea following suit. In the EU, the SFDR (Sustainable Finance Disclosure Regulation) became applicable in March 2021. Its scope captures financial market participants and financial advisers operating in the EU and sets specific rules for how and what sustainability-related information they need to disclose.

5 General Circulation Models (GCMs) looking at the response of the environment's physical processes (e.g. temperature, sea level rises) to rising greenhouse gas emissions as well as Integrated Assessment Models (IAMs) focusing on the interaction of climate variables with climate policies and the economy have been around for many years. They have been increasing in sophistication and usefulness. However, these were developed with climate scientists and policymakers in mind, not financial investors.

2. **Flexible, Consistent and Integrated** - Models should allow flexibility in combining views about emissions pathways, temperature outcomes, government policies, technological mixes, the macroeconomy and markets in a consistent framework that accounts for feedback loops amongst these factors. For example, a policy measure like carbon pricing will change the relative price of carbon, thereby affecting the demand for fossil fuels and adoption of low carbon technologies. This in turn will affect the emissions pathways and temperature outcomes.

3. **Current** - Models should incorporate the latest scientific research such as the sensitivity of global temperature to the amount of accumulated emissions, and the impact of global warming on economic activity. For instance, older versions of integrated assessment models use physical damage functions that are based on historical observations of activity and temperatures at the macro level of countries, which can significantly underestimate the physical impacts of global warming over the long term[6]. The latest research on chronic physical risks (using granular local level economic analysis) shows that there is a non-linear decline in labour and agriculture productivity beyond an optimal temperature level (at around 13ºC) due to the ecological and biological impacts of higher temperatures[7].

GIC's Approach to Climate Change Scenario Analysis

To achieve robust *financial* modelling of climate scenarios, **GIC's approach is to not rely on one single model, but to triangulate between different top-down and bottom-up modelling methods.**

6 Kahn et al, "Long-Term Macroeconomic Effects of Climate Change: A Cross-Country Analysis", IMF Working Paper, 2019.

7 Burke, Hsiang, Miguel "Global non-linear effect of temperature on economic production", Nature, 2015.

A. Top-down approaches look at how climate change related-drivers affect returns of asset classes as well as impacts at the country and sector levels.

B. Bottom-up approaches look at the impact of climate change-related drivers on cash flows (e.g. revenues, and costs) at the individual security level.

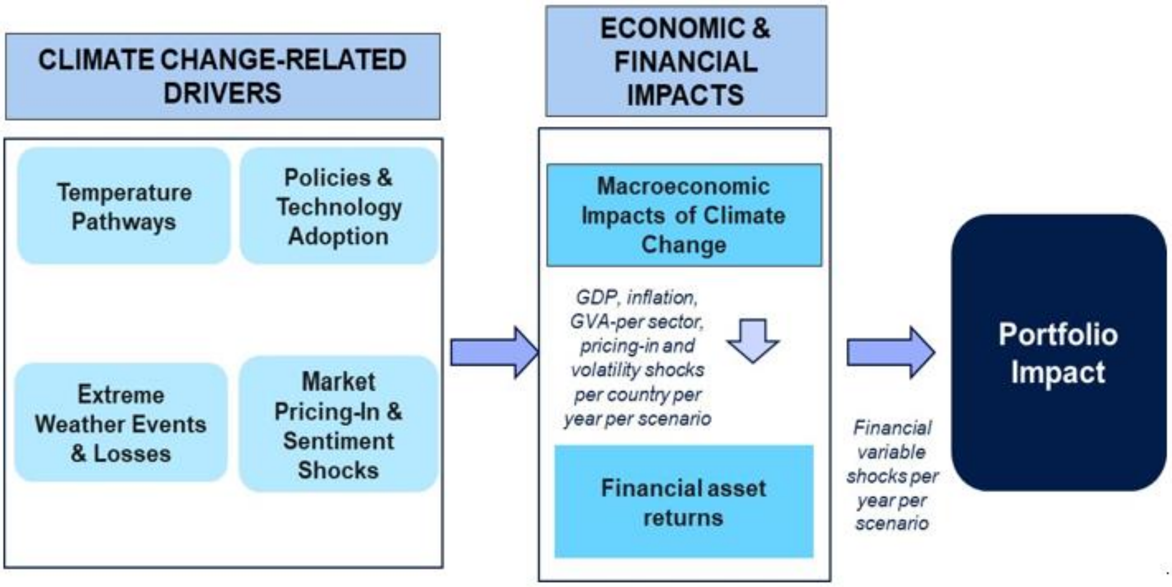
C. We compare our analyses with the results that other institutions have developed, considering differences in scenarios and modelling methodologies.

In the following section, we focus on the Top-Down approach only. For the development of climate scenarios and top-down analysis of climate change-related impacts on investment portfolios, GIC partnered with Ortec Finance, given that their capabilities addressed *most* of our requirements regarding the financial modelling of climate change.

Ortec Finance Climate MAPS Modelling Methodology

The Climate MAPS tool is jointly developed by Ortec Finance and Cambridge Econometrics. It combines climate science modelling with Energy-Environment-Economy (E3ME) macro modelling, extreme weather risk modelling (Climate PREDICT), and stochastic financial modelling of broad asset classes. The model uses empirically based climate and financial modelling to best reflect the how the real world works in practice. Figure 2 shows how the process looks like.

Figure 2: Process for Translating Climate Scenarios to Portfolio Impacts (Climate MAPS Tool)



Source: GIC, Ortec

- First, there are a set of inputs based on different climate change scenario narratives we developed. These include temperature and carbon emissions pathways, policy and technological assumptions, extreme weather events and losses, as well as views about how smooth or disruptive markets will price in climate change-related shocks.
- Second, the economic impacts from these different climate change-related drivers are estimated using an econometrics model that has interactions between the environment, energy and economy. This integrated E3ME model then generates the macro impacts from climate change including real GDP growth, inflation, labour productivity and (sector-country) level gross value-added growth.
- Third, extreme weather events assumptions are developed using Ortec Finance's proprietary extreme weather risk model, Climate PREDICT. Ortec Finance's own urbanization-based risk algorithm and Economic Amplification Ratios uses various inputs including data on extreme weather events and losses from Munich RE's NatCatService to calculate forward looking direct and second-order GDP impacts from extreme weather risks.

- Fourth, GDP and inflation shocks from the macro and extreme weather models, market pricing-in risks and sentiment shocks are combined in Ortec Finance's stochastic financial model to derive climate change-driven impact on risk-return parameters (e.g. return and volatility) of asset classes.
- Lastly, the stochastic financial model produces outputs which can then be used to calculate aggregate portfolio impacts.

The Climate MAPS tool is thus able to break down the climate change-related impact on macroeconomic variables and asset class returns into the various drivers of climate change (as outlined in Figure 1 and 2):

- Gradual (or chronic) physical risk
- Acute physical risk (extreme weather)
- Transition risk, including both policy and disruptive technology impacts
- Market pricing-in risk and sentiment shock

More information about the Climate MAPS approach is elaborated in Annex A.

Analysis from Three Key Climate Change Scenarios

Our three climate change scenarios are shaped by assumptions about how the different climate change-related drivers evolve:

1. **Paris Orderly Transition**: This is characterized by an early, orderly and ambitious transition to a 1.5˚C warming trajectory by 2100. It includes physical risks associated with 1.5˚C. The market's pricing-in of transition and physical related risks are smoothed out.
2. **Delayed Disorderly Transition**: This is GIC's bespoke scenario. It assumes that the world is slow to implement climate policies, but when a series of extreme weather events that is higher in frequency and intensity versus historical experience occurs and

results in a sharp global GDP shock[8], the world shifts gear and acts. Policies required (such as regionally differentiated carbon pricing and subsidies for clean technologies) are much bigger than what is required in the Paris Orderly Transition due to the delay in taking climate mitigation actions. Markets price future climate change-related risks over a much shorter period compared to the Paris Orderly Transition. There is also a sharp sentiment shock as markets overreact to the sudden extreme weather and policy shocks. The transition is thus disorderly with equity markets falling sharply. However, over time the sentiment shock (which is not fundamentally driven) dissipates and economies and markets recover.

3. **Failed Transition**: As this scenario assumes only current policies are implemented, climate change - related physical impacts - both chronic and acute - are extremely severe as the average global temperature increases to nearly 4ºC above pre-industrial levels by 2100. In this scenario, we see markets pricing in physical risks including those occurring in the post-2050 period so that financial impacts are felt even before the physical risks actually manifest.

The temperature pathways associated with these three scenarios, and a brief overview of the key drivers of the scenarios are presented in Figures 3 and 4. These scenarios also map broadly to the three reference scenarios recommended by the NGFS in June 2020[9].

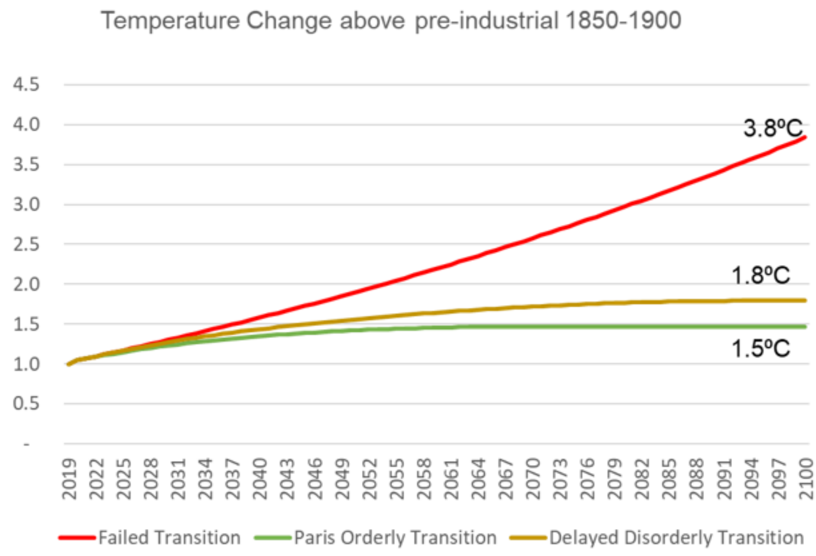
As it is difficult to paint all possibilities and even more challenging to integrate them into portfolio analyses and subsequent decisions, we have selected “bookend” scenarios where the Paris Orderly Transition is an optimistic outcome in terms of global warming combined with a set of very aggressive policy actions, while the Failed Transition is a pessimistic one with no additional policy actions beyond what governments have already implemented. To capture nuances and a more plausible pathway, the Delayed Disorderly

8 This is a GDP shock over a one year period that is globally differentiated, depending on the assumptions about severity of extreme weather shocks affecting each country.

9 “NGFS Climate Scenarios for central banks and supervisors”, June 2020.

Transition explores how stressful market conditions could be if the world procrastinates, and how investment portfolios will behave during any interim climate change-related shocks.

Figure 3: Temperature Pathways in the Three Climate Scenarios



Source: GIC, Ortec

Figure 4: Overview of GIC's Climate Scenarios

Drivers	Paris Orderly Transition	Delayed Disorderly Transition	Failed Transition
Global warming by 2100	1.5ºC	1.5-2ºC	Close to 4ºC
Policy and technology assumptions	**Early policy measures** (e.g. EU-style emissions trading scheme implemented globally and for most sectors). Significant investments in and adoption of low-carbon technologies	Policy action similar to Failed Transition in first phase of scenario. However, **a surge in extreme weather events globally** and realization of higher-than-expected climate sensitivity triggers **sudden and disruptive policy actions**.	Continuation of **current** policies.
Market pricing-in assumptions	Pricing in of climate risks occurs smoothly and gradually	Pricing in of climate risks occurs abruptly and within a short period of time.	Physical risks up to 2050 are priced before 2030, and physical risks post 2050 are priced before 2040
Sentiment shock assumptions	No additional sentiment shock	Additional sentiment shock is triggered by the sudden and disruptive policies but market recovers from sentiment shock eventually	No additional sentiment shock

Source: GIC, Ortec

Results & Key Insights

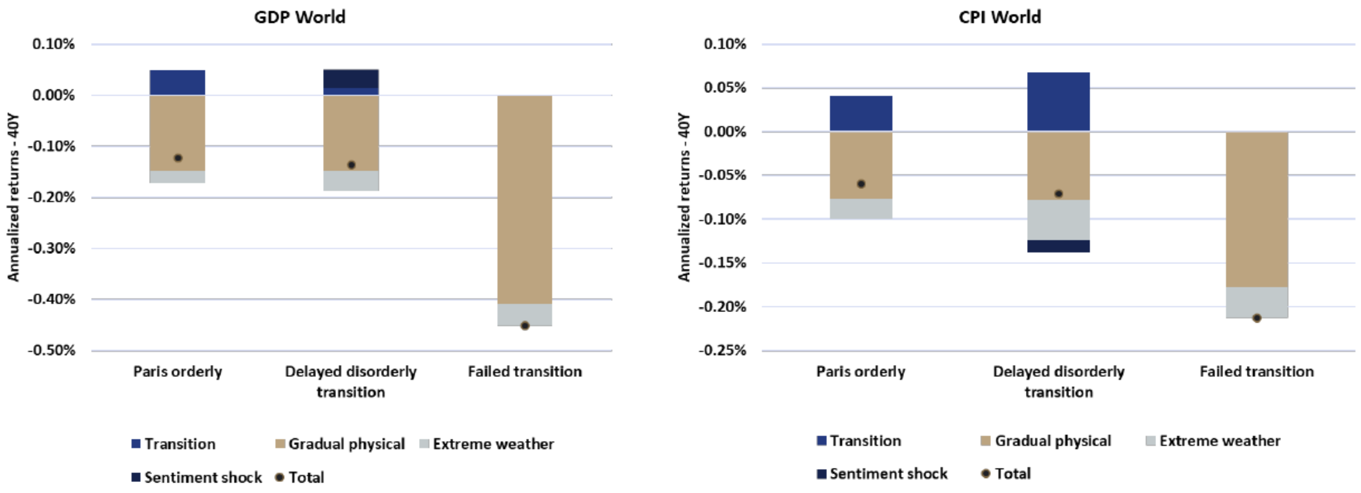
We applied the scenarios and methodology outlined above to a simplified global investment portfolio of 60% global equities and 40% global bonds ("60/40")[10]. The key impacts on the economy, capital markets and the 60/40 portfolio are summarized in the subsequent sections.

Macro Impact

Climate change-related drivers have a negative long-term impact on global GDP and inflation when compared to a climate uninformed baseline, due mainly to physical risks (see Figure 5).

Gradual (or chronic) physical risks have long-term adverse effects on labour and economic productivity. Extreme weather impact (or acute physical risk) is also negative on macroeconomic growth but to a much smaller degree than gradual physical risks.

Figure 5: Expected Impact of Climate Change Drivers on Macro Growth and Inflation[11]



Source: GIC, Ortec

10 Equities portfolio comprises of markets in the US, Canada, Europe, Japan, Developed Markets (Pacific) and Emerging Markets. Fixed Income are nominal government bonds issued in US, Japan, France, Italy, Germany and UK. The returns data series from these markets are based on the benchmark indices in Ortec's financial model.

11 While the impact of climate drivers on global inflation is negative over the long-term due to the deflationary impacts of physical risks on growth, we would caveat that further research is needed to assess how a rise in physical risks may result in scarcity of resources and exert upward pressures on inflation. For this scenario study, the behaviours of GDP and inflation to the sentiment shock was based on the experience of the Global Financial Crisis of 2008-2009. Post the sentiment shock, GDP recovered sharply to more than offset the initial negative shock while inflation did not recover as much, resulting in a net positive impact on GDP and a net negative impact on inflation.

Transition risk impacts are net positive for global growth. But these effects are mostly felt when climate-related policy actions are implemented, and the energy transition is ongoing i.e. during the first 10 years or so of the 2021-60 period in our climate scenarios. Transition risks are net positive on global growth due to:

(i) carbon taxes being re-distributed back into the economy through either lower general taxes or higher subsidies for the clean energy sectors, resulting in a positive fiscal multiplier effect on the economy.

(ii) subsequent investments in clean energy sectors more than offsetting the decline in demand for traditional fossil fuels, as the investments required, innovation and resulting productivity gains act as economic stimulants.

Transition risks exert an upward, demand-pull inflationary impact due to higher carbon prices and an increase in investment spending on clean technologies.

Inflationary pressures are higher in the Delayed Disorderly Transition as the costs of financing the energy transition rise with policy procrastination. As a result, there is less scope for governments to recycle revenues generated from carbon pricing to lower personal taxes (e.g. VAT or income tax) to buffer the increasing costs of energy for individuals, thereby increasing inflationary pressure.

Finally, our analysis shows a wide dispersion of growth impacts across countries, and winners and losers also vary according to the different scenarios. For example:

- In the Paris Orderly Transition, net fossil fuel exporters would see higher negative growth impact due to the energy transition compared to net fossil fuel importers.
- In the Failed Transition, negative physical impacts are greater in countries with higher starting average temperatures. While countries near the poles are expected to see relatively faster warming, the impact on economic growth is smaller given their lower starting temperatures. Some countries may even benefit from previously inhabitable cold regions becoming more productive.

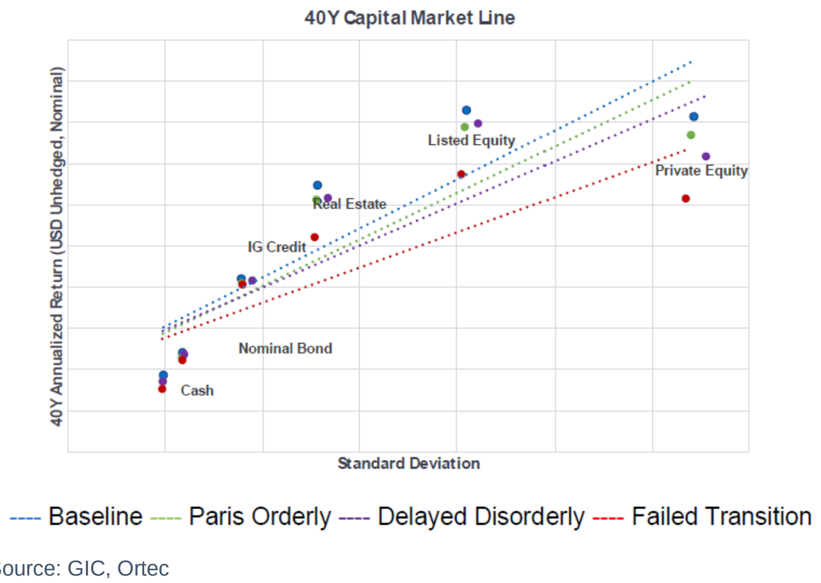
Capital Markets Impact

Physical and transition risks are mostly negative for broad asset classes compared to a climate uninformed baseline. Risk assets like equities and real estate are more sensitive to climate change compared to bonds and cash. This results in capital market lines being flatter in climate scenarios relative to the climate-uninformed baseline (see Figure 6).

The response of risk assets (equities and real estate) to physical risk drivers is negative, like what we observe in the real economy. However, the impact of transition risks is negative, as compared to its positive impact on global economic growth. This largely reflects the difference in the composition of equity markets versus the real economy. Global equity markets have a higher exposure to the US, which is a net exporter of fossil fuel-based energy and thus adversely affected by the energy transition.

Within the equity markets, most sectors see downside risks, except for low carbon electric utilities. We observe that equity markets with very low exposures to low carbon electric utilities (e.g. emerging markets) have more potential to outperform in the transition scenarios as the room for the sector to grow is much larger than those which already have established low carbon electric utilities.

Figure 6: Capital Markets Line



Source: GIC, Ortec

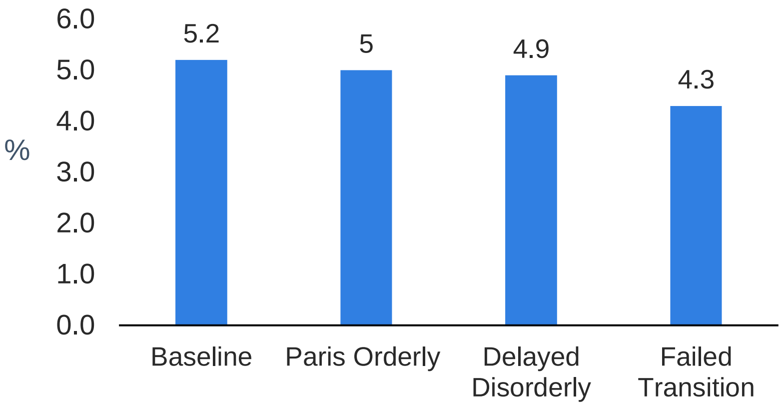
Investment Portfolio Implications

Climate change has a long-term negative impact on a global 60/40 portfolio in the order of minus 10-30% relative to a climate uninformed baseline, largely driven by physical risks.

The annualized nominal returns over a 40-year period for the 60/40 portfolio ranges from 4.3 to 5.0% in the three scenarios, versus 5.2% in a climate uninformed baseline (see Figure 7a). This is significant as it translates to cumulative returns in climate scenarios being 10% to 30% lower over 40 years (see Figure 7b).

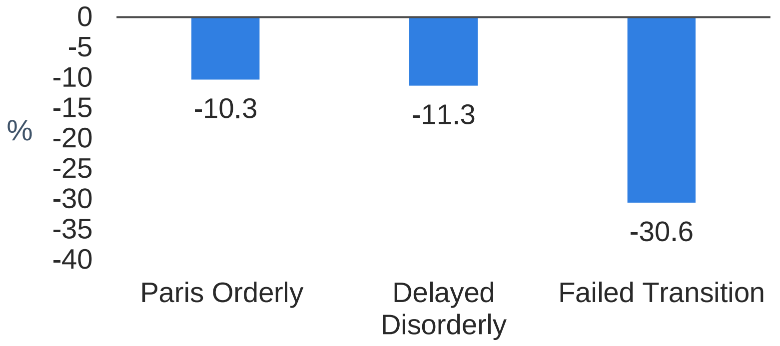
While risk assets may still deliver positive returns in the long term with climate change, the returns are likely to be lower than a climate uninformed scenario, which assumes policies that have already been implemented and no further global warming beyond what has already occurred today (about 1ºC). Hence, investors may be surprised by the long-term underperformance of the portfolio relative to their expectations.

Figure 7a: 40-year Annualised Nominal USD Returns of 60% Global Equities /40% Sovereign Bonds portfolio



Source: GIC, Ortec

Figure 7b: 40-year Cumulative Nominal USD Returns of 60/40 portfolio Vs Climate Uninformed Baseline



Source: GIC, Ortec

While it is generally accepted that there are transition risks in the investment portfolio, **long-term physical risks, especially chronic physical risks, may have a much more significant impact on investments.** With growing investor awareness and an availability of data and physical risk assessment methodologies, physical risk impacts can increasingly be incorporated into analyses.

In the medium term, climate-related shocks could result in increased market volatility that long-term investors should prepare to navigate. When and how much markets will price in future climate change-related risks, and whether markets over-react to climate change-related policies and news can impact volatility in the markets.

- In the Delayed Disorderly Transition, during the year when disruptive extreme weather events hit the world and sharp policy actions are implemented, the global economy could see a negative GDP impact. The global 60/40 portfolio is expected to experience a sharp fall due to the negative growth shock as well as a sentiment shock hitting the global equities market.
- Another possible period of volatility is when markets price in future physical risks, especially physical impacts in the post-2050 period, in the Failed Transition. While the sentiment shock in the Delayed Disorderly Transition is a temporary shock that markets

eventually recover from, the pricing in of future physical risks is expected to be a permanent impairment to the portfolio's returns as physical risks are not reversed in the Failed Transition.

Since climate risk is an imminent challenge for long-term investors, it is critical for them start building capabilities to integrate transition and physical risk assessments into their investment processes.

Top-down Model Limitations

By applying climate scenario analysis to their portfolios today, investors can already better articulate the potential impact and seize the opportunity to consider what can be done to make their portfolios more climate resilient.

There are of course still limitations to the top-down scenario approach:

- Climate science models have not fully accounted for feedback loops and tipping points from warmer temperatures accelerating ice-sheet melting, which would then further increase sensitivity of the earth's average temperature to greenhouse gas emissions.
- Climate impact models have generally not been able to account for the implications of climate change-related migration on economies and markets.
- Financial models are not, as yet, able to properly price the impact of physical risks on scarcity and the implications for inflation and related assets.

In response, what investors can do is to keep updated with the latest research, and be at the frontier of designing plausible climate change scenarios and quantifying their impact on portfolios.

Conclusion

What we have outlined is a top-down approach to estimating the impact of climate change-related risks on long-term investment portfolios via climate change scenarios. Very long-term cash flow impacts and risks become relevant to investors when we consider how future risks might be priced into markets and whether the markets would over-react. While this requires various assumptions and results in a wide dispersion of outcomes, it is still good discipline and prudent for investors to be prepared and undertake such analysis. The three scenarios used, including GIC's bespoke Delayed Disorderly Transition, can be a useful reference for long-term investors contemplating the use of climate change scenario analysis. We suggest three ways that investors can use these outputs:

- **Asset allocation** by incorporating climate change-related scenarios into the asset allocation process and considering the impact of climate change on expected returns of asset classes. Scenario analysis is a well-established process and a fundamental building block that GIC uses for its top-down and bottom-up capital allocation processes[12]. It is a forward-looking assessment and helps GIC better anticipate the range of upside and downside risks that could affect markets. This is also aligned with one of GIC's investment principles, which is to prepare for, and not predict possible states of the future.

- **Risk management** by using the most disruptive climate scenario(s) as a stress test for the resilience of the investment portfolio and considering how to better navigate through the volatility that could affect markets. Scenario analysis with sufficient granularity in terms of how different countries and sectors are affected, helps us identify where the most vulnerable parts of the portfolio are. Deeper dives can then be conducted in these countries and sectors.

12 https://www.gic.com.sg/thinkspace/scenario-planning-for-portfolio-resilience-in-an-uncertain-world/

- **Climate change integration into active investment processes** by using the assumption inputs (e.g. carbon pricing) and intermediate outputs (e.g. demand for energy sources like coal, oil, gas, renewables as well as adoption rates of technologies like electric vehicles) for bottom-up investment teams to incorporate into their assessment of companies. For example, forward-looking carbon prices can be combined with data on companies' carbon emissions to estimate impact of carbon pricing on companies' earnings and valuations.

Ultimately, **GIC recommends combining a top-down and bottom-up modelling approach to provide a more holistic assessment of climate change related impacts on investment portfolios.** Notwithstanding, we hope that the sharing of our perspectives from the top-down scenario process can contribute to accelerating the integration of climate change-related considerations into investment processes around the world.

ANNNEX A: Ortec Finance's Climate MAPS Methodology

A key characteristic of Climate MAPS is that it is holistic in its approach. This is expressed in the following manner:

- **Broad coverage of climate-related risks:** Climate MAPS models transition related risks and opportunities as well as physical risks (both slow onset and extreme weather impacts). It also takes into account the potential effects of markets 'pricing-in' future transition and physical risks.
- **Covers all asset classes on the basis of a consistent set of assumptions:** The modelling techniques used ensure that all the asset classes are 'climate-shocked' on the basis of consistent set of assumptions. Therefore, more granular outcomes at, for example the sector, region or asset class level can safely be aggregated to the level of the whole portfolio.
- **Captures 'systemic risk at a granular level':** The model is built up of granular technology and policy developments that translate to economic and financial impacts at the sector and regional level. The model specializes in capturing economic-financial interlinkages and feedback loops. For example, less demand for a country's fossil-fuel exports will be felt far beyond the fossil fuel manufacturing companies themselves. Effects will reverberate in areas such as employment, government revenues and all the sectors related to the fossil fuel industry. The tool is therefore able to more accurately reflect the total level of climate-related economic risks and opportunities in a given market than an approach that is based on the aggregation of individual companies' or assets' risks.

Another important attribute of the Climate MAPS tool is the use of empirically based climate and financial modelling to best reflect how the real world works in practice:

- **Assumption about market efficiency**: The macro-model does not assume perfectly efficient markets and is able to capture the dynamics of loans and investment.
- **Empirical based:** The financial model is based on more than 100 years of econometric data.
- **Incorporation of latest climate science research and modelling:** The model is rooted in strong climate science using the latest literature. An example is the relationship between temperature rise and economic, agricultural and industrial productivity. The model also takes into account the 'latitude effect' when modelling physical risks. The latitude effects show that the Earth's poles are prone to relatively faster warming. Finally, the tool makes use of a proprietary algorithm, Climate PREDICT, that intelligently scales extreme weather events and associated financial impacts in line with warming and urbanization trends.

As is the case with all models, Climate MAPS has its limitations:

- There are some specific areas that require further research including, for example, land-use emissions, the impact of scarcity on inflation, impacts of migration and social conflict, biodiversity loss and climate tipping points.
- Also, the model is not the best fit for modelling the risks at an individual company level. Hence, GIC's approach of complementing a top-down modelling approach with a bottom-up approach will help provide a more holistic assessment of climate change related impacts on its investment portfolios.

Acknowledgements

We wish to thank and acknowledge the valuable contributions of all these individuals for their participation, inputs, and review in the development of this study.

From GIC

Kevin Bong, Managing Director
Wendy Wong, Senior Vice President
Kevin Kwan, Vice President
Wong De Rui, Vice President

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