ISDA® Safe, Efficient Markets

Celebrating 40 Years

February 2025

Climate Risk Scenario Analysis for the Trading Book: Phase 3

CONTENTS

EXECUTIVE SUMMARY

Climate scenario analysis has been an area of increasing focus for banks and financial institutions in recent years. Firms need a better understanding of the short- and longer-term financial risks associated with climate change, especially given the changing regulatory landscape and increased focus on mitigating the direct impact of climate-related risks. Climate scenario analysis for the trading book poses a particular set of challenges, given the need to develop bespoke, short-term scenarios that include a detailed set of market risk factors.

Phase 3 has two components: an industry survey to assess industry progress and operational readiness; and an expansion of the market risk factors for the transition risk scenario developed in Phase 2

In response to these challenges, ISDA has engaged in a multi-phase project to develop a framework for climate scenario analysis for the trading book. The two main factors that differentiate ISDA's work from previous efforts are the focus on very short-term horizons that are applicable to the trading book and the proposed calibration of market risk factor shocks for each scenario.

In 2023 and 2024, ISDA published detailed papers covering Phase 1[1] and Phase 2[2] of this initiative. This paper sets out the work completed during Phase 3. This phase has two components: a survey to assess industry progress and operational readiness; and an expansion of the market risk factors for the transition risk scenario developed in Phase 2.

Operational Readiness Survey

- Survey results have shown that banks have progressed from a basic approach to a more mature approach to embedding climate risk in trading book scenario analysis, from scenario design and modeling to application.
- Banks have expanded their scenario analysis capabilities to consider a wider scope of market risk asset classes, including FX, interest rates, equities and credit. There has been less progression in commodities, which remains comparable to the survey results in Phase 1.
- Banks continue to rely primarily on expert judgment in the assessment of climate risk, but the survey results show a shift to a combined top-down and bottom-up approach to modeling, suggesting enhanced consideration of sector- and asset-level granularity.
- There is continued strong interest in ISDA's short-term scenarios, which are widely used alongside the short-term scenarios developed by the Network of Central Banks and Supervisors for Greening the Financial System (NGFS).

Market Risk Factor Expansion

- In Phase 3, the framework has been expanded from the EU, Japan, the UK, the US, Brazil and India to also include Australia, Canada, China and South Africa.

[1] A Conceptual Framework for Climate Scenario Analysis in the Trading Book, ISDA, July 2023, www.isda.org/2023/07/12/a-conceptual-framework-for-climate-scenario-analysis-in-the-trading-book/

[2] Climate Scenario Analysis in the Trading Book – Phase II, ISDA, February 2024, www.isda.org/2024/02/12/climate-scenario-analysis-in-the-trading-book-phase-ii/

- The exercise required the calibration of macroeconomic shocks – gross domestic product (GDP), interest rates and inflation – for the new geographies.

- In Phase 3, an additional 99 market risk factor shocks were developed across asset classes, in addition to the 73 market risk factor shocks developed in Phase 2.

1. INTRODUCTION

1.1. Background: Phases 1 and 2

In Phase 1, conducted in 2023, ISDA collaborated with more than 30 member banks to develop a conceptual framework for climate scenario analysis and determine the key considerations when designing and implementing short-term scenarios for the trading book. ISDA developed 74 survey questions and received responses from more than 25 member banks.

The 2023 survey covered four main areas:

1. Scenario narrative;
2. Shocks and calibration;
3. Applications of climate scenario analysis; and
4. Modeling frameworks.

In Phase 2, using the results of the Phase 1 survey, ISDA piloted the conceptual framework by developing three short-term climate scenarios for the trading book:

1. Physical risk;
2. Transition risk; and
3. Combined physical and transition risk.

These scenarios were developed to be consistent with existing long-term scenarios but shortened to be appropriately severe and plausible for the short-term horizon required to make them relevant for the trading book. This was achieved by calibrating transition and physical risk shocks as one-off, permanent shocks at the beginning of the scenarios, rather than assuming they occur gradually over many years. Phase 2 yielded a set of market risk factor shocks, as well as a set of macroeconomic shocks across developed markets (the EU, Japan, the UK, and the US) and emerging markets (Brazil and India).

Phase 3 continues the work conducted in Phases 1 and 2, with an expansion to new geographies and the subsequent addition of new market risk factor shocks for those geographies, as well as a survey tracking banks' progress since the Phase 1 survey. Consistent with Phases 1 and 2, ISDA commissioned Deloitte to support Phase 3.

1.2. Objectives of Phase 3

In Phase 3, two specific objectives were set:

1) Conduct a survey to assess industry progress on climate scenario analysis for the trading book;
2) Increase the number of geographies and expand the range of market risk factors covered.

The survey addressed a subset of the questions covered in Phase 1 and was intended to assess progress over the past year in certain areas: selection of scenarios; shock calibration; application; and modeling frameworks. Participating firms can use the results to assess the maturity of their climate scenario analysis capabilities against the broader industry.

During Phase 2, the ISDA working group expressed an interest in expanding the set of market risk factor shocks and macroeconomic shocks to new geographies, specifically for the transition risk scenario. The objective of Phase 3 was to produce the additional shocks for four new geographies – South Africa, China, Australia and Canada. The combination of market risk factor shocks produced across Phases 2 and 3 provide a more complete set of shocks for banks to use for their own climate scenario analysis. To maintain consistency with Phase 2, Phase 3 focused on the same asset classes and the same liquidity horizons: one day; 10 days; three months; and one year.

2. PHASE 3 SURVEY

2.1. Introduction[3]

The Phase 3 survey comprised 21 questions, primarily selected from the Phase 1 survey, all of which focus on banks' operational readiness to conducting climate scenario analysis for the trading book. Responses were received from 24 member banks (27 responses were received for the Phase 1 survey).

The survey was constructed using the same themes as Phase 1:

1. **General** – general progression of climate risk scenario analysis.
2. **Scenario narratives** – which scenarios and time horizons are most popular.
3. **Shocks and calibration** – different approaches to calibrating market risk shocks.
4. **Applications** – level of integration across different risk management activities, including internal capital adequacy assessment process (ICAAP) and disclosures.
5. **Modeling frameworks** – progress in integrating climate risk into market risk models.

2.2. Overview of Results

The survey provides clear evidence that banks have progressed in their development and use of climate scenario analysis for the trading book. Banks assess themselves as having progressed from a basic approach to a more mature approach to embedding climate risk in trading risk scenario analysis. Furthermore, there has been a general increase in the granularity of trading book climate assessments.

Key findings from the survey include:

1. Climate scenario analysis for the trading book has become more mature;
2. Banks have broadened the asset classes they consider in climate scenario analysis for the trading book;
3. The scenario families developed by ISDA and the NGFS are the ones that most banks intend to use for climate scenario analysis for the trading book;
4. More banks are now tailoring existing scenarios to make them appropriate for the trading book and still prefer very short-term horizons;
5. Banks are using a mix of top-down and bottom-up approaches to assess physical and transition risks;
6. Banks are increasingly using a combination of expert judgment and data-driven assessment to calibrate climate risk shocks;
7. Climate risk in the trading book is increasingly being assessed as part of ICAAPs and internal liquidity adequacy assessment processes (ILAAPs). Banks have indicated they do so at a high level rather than at a granular level, by asset or material risk type;
8. Disclosure of trading book climate scenario analysis is limited;
9. Further analysis is needed before banks can use climate scenario analysis in the trading book for bank strategy;
10. The primary use case for climate scenario analysis in the trading book continues to be regulatory compliance.

[3] The results of the Phase 1 and 3 surveys were compared to determine the level of progress that has been achieved between 2023 and 2024. Several questions added that were not asked in Phase 1, so these questions have no comparison with Phase 1. Most results were reported as a percentage of the total number of survey respondents, but where this is not the case, it has been specified how the values were calculated

Survey Results: General Progression

The 'General' section of the survey aimed to identify the overall progress banks have made in climate scenario analysis for trading book exposures.

The key takeaways from the survey are:

1. Climate scenario analysis for the trading book has become more mature.
2. Banks have broadened the asset classes they consider in climate scenario analysis for the trading book.

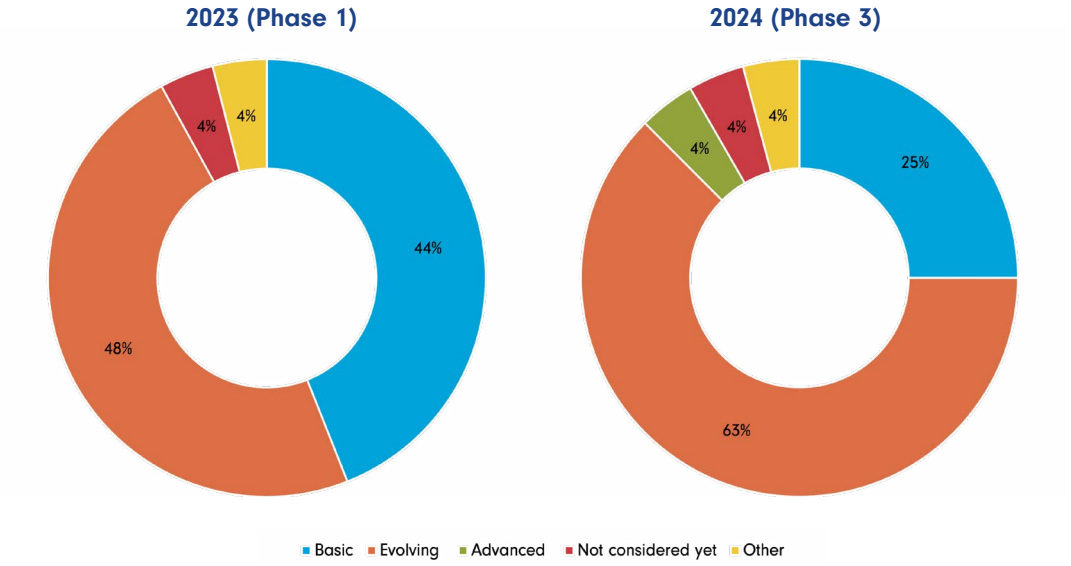
KEY TAKEAWAY 1: Climate scenario analysis for the trading book has become more mature.

Overall, ISDA has observed that more banks now consider their approach to be 'evolving' or 'advanced' in comparison to where it was in the previous phase. These results indicate that when banks are asked to assess their experience over time, there is increasing sophistication in climate scenario analysis for the trading book.

Overall, ISDA has observed that more banks now consider their approach to be 'evolving' or 'advanced' in comparison to where it was in the previous phase

As shown in Figure 1, 63% of total respondents to the Phase 3 survey indicate they consider their approach to be 'evolving', compared to only 48% in the Phase 1 survey in 2023. Furthermore, 25% of respondents to the Phase 3 survey indicated they consider their approach to be 'basic', compared to 44% in 2023. Additionally, 4% of total respondents in 2024 indicated they consider their approach to be 'advanced,' compared to no respondents in Phase 1.

Figure 1: Firms' Assessment of Progress on Climate Scenario Analysis for the Trading Book, 2023-2024



Banks were also asked which asset classes they consider in climate scenario analysis for the trading book.

KEY TAKEAWAY 2: Banks have broadened the asset classes they consider in climate scenario analysis for the trading book.

In identifying the relevant asset classes for climate scenario analysis for the trading book, ISDA observed that banks increasingly include credit, equities, FX and interest rates in their current climate scenario analysis. In the future, all banks intend to include credit, FX and interest rates.

As shown in Figures 2 and 3, 92% of total survey respondents in 2024 indicated they currently undertake climate scenario analysis for credit, compared to 74% in 2023. For interest rates and FX respectively, 88% and 83% of total respondents indicate they currently undertake climate scenario analysis, compared to 59% and 56% in 2023. Three quarters of respondents currently conduct scenario analysis for equities, compared to 59% in 2023, and 54% for commodities, compared to 56% 2023.

Figure 2: Asset Classes Included in Climate Scenario Analysis for the Trading Book (2023)

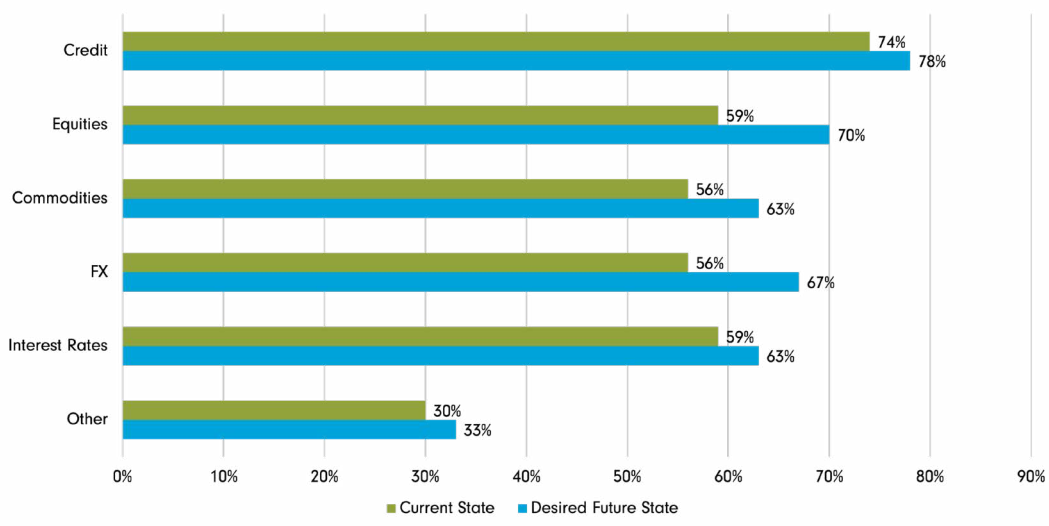
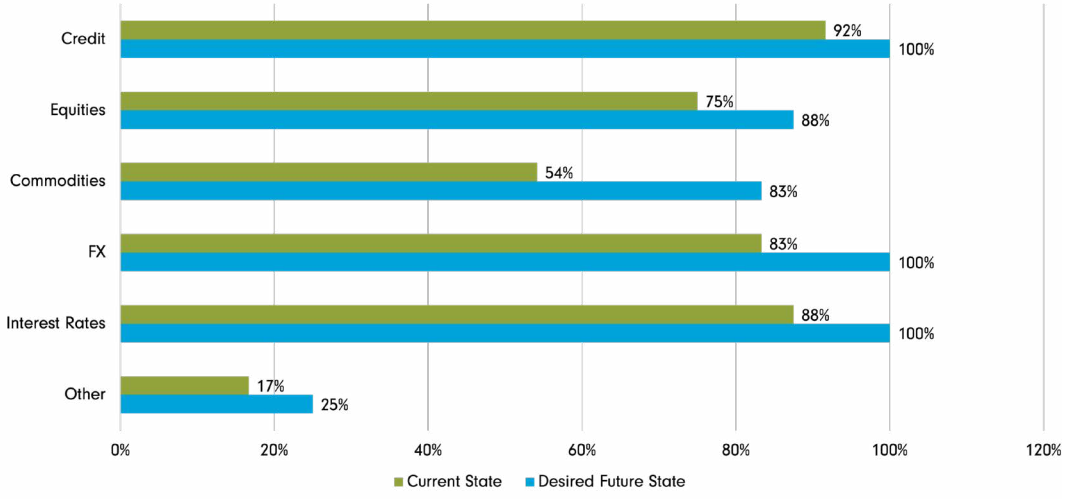


Figure 3: Asset Classes Included in Climate Scenario Analysis (2024)



Survey Results: Scenario Narrative

The aim of this section of the survey was to identify the most popular and relevant scenario narratives for banks. Overall, the responses indicated the following results:

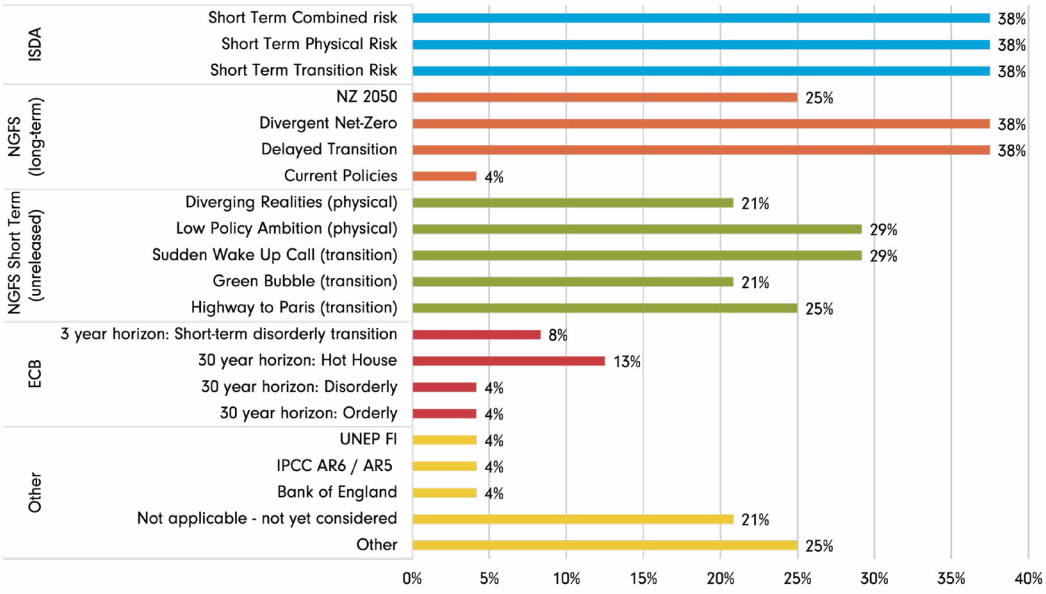
3. The scenario families developed by ISDA and the NGFS are the ones that most banks intend to use for climate scenario analysis for the trading book.
4. More banks are now tailoring existing scenarios to make them appropriate for the trading book and still prefer very short-term horizons.

Banks were asked which pre-determined climate scenarios they currently use and which ones they intend to use in the future. Internally developed scenarios are currently the most popular, with the NGFS long-term delayed transition and the European Central Bank's three-year disorderly transition scenario the second most popular. Banks were further surveyed on which scenarios they intend to use in the future.

KEY TAKEAWAY 3: The scenario families developed by ISDA and the NGFS are the ones that most banks intend to use for climate scenario analysis for the trading book.

As shown in Figure 5, 38% of respondents intend to use the ISDA scenarios, including physical, transition, and combined risk. In addition, 38% intend to use the NGFS long-term divergent net-zero and delayed transition scenarios. The NGFS short-term scenarios, which have not yet been published, were also popular, particularly the low policy ambition (physical risk) and sudden wake-up call (transition risk) at 29%[4].

Figure 4: Pre-determined Climate Scenarios Intended for Future State



Banks were asked if they modify existing scenarios for the trading book and what time horizon they consider to be most relevant.

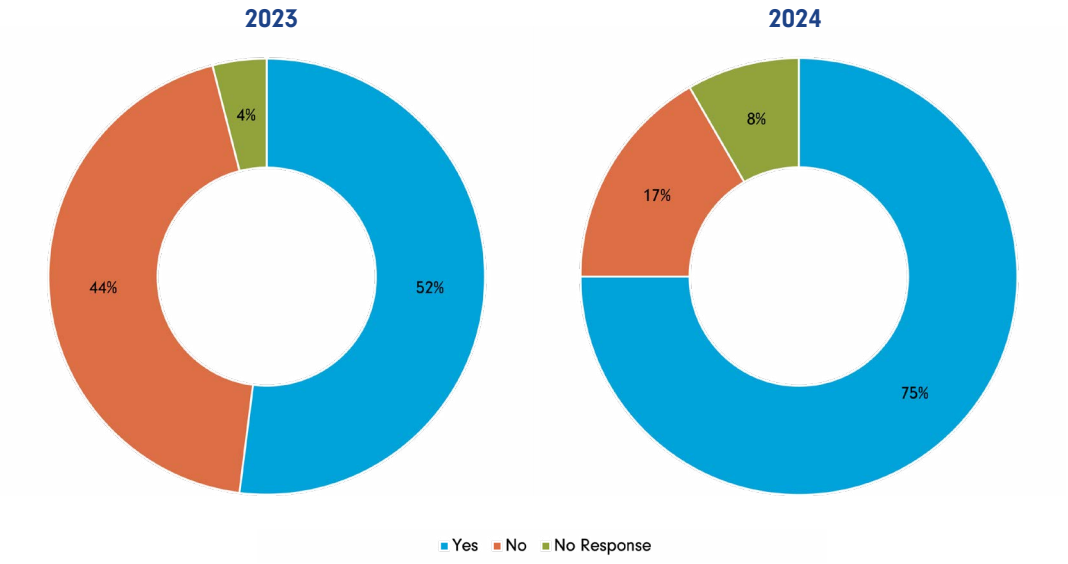
[4] Figure 4 shows the percentage of total respondents that selected each scenario

KEY TAKEAWAY 4: More banks are now tailoring existing scenarios to make them appropriate for the trading book and still prefer very short-term horizons.

As well adopting ISDA scenarios, an increasing number of banks are modifying pre-existing scenarios to make them more appropriate for the trading book.

As shown in Figure 5, 75% of total survey respondents in 2024 indicated they modify their existing scenarios to make them more relevant to the trading book, compared to 52% in 2023. This is consistent with a more mature approach to scenario design[5].

Figure 5: Comparison Between Percentage of Banks that Modify Existing Climate Scenarios for the Trading Book, 2023-2024



Banks were also asked what time horizon they see as most relevant for climate scenarios. Their answers remained the same as in 2023 – that the most relevant time horizon is the sudden shock (point-in-time) scenario.

As well adopting ISDA scenarios, an increasing number of banks are modifying pre-existing scenarios to make them more appropriate for the trading book

Survey Results: Shocks and Calibration

This section of the survey was used to understand banks' approaches for calibrating shocks for market risk. Overall, responses indicate the following results:

5. Banks are using a mix of top-down and bottom-up approaches to assess physical and transition risks;
6. Banks are increasingly using a combination of expert judgment and data-driven assessment to calibrate climate risk shocks;

To identify shifts in the use of top-down and bottom-up versus combination approaches, banks were surveyed again in this phase on which approach they take, between physical risk and transition risk.

[5] Figure 5 shows the percentage of total respondents that selected each option

KEY TAKEAWAY 5: Banks are using a mix of top-down and bottom-up approaches to assess physical and transition risks.

Between 2023 and 2024, there has been an increase in banks using a combination of top-down and bottom-up approaches to climate scenario analysis for both physical and transition risks.

As shown by comparing Figures 6 and 7, 29% of respondents selected a combination of the top-down and bottom-up approaches to physical risk in 2024, compared with 11% in 2023. This is paired with an increase in the response rate for physical risk and a reduction in bottom-up approaches for both physical risk and transition risk in 2024.

Figure 6: Top-down vs. Bottom-up Approaches to Climate Scenario Analysis (2023)

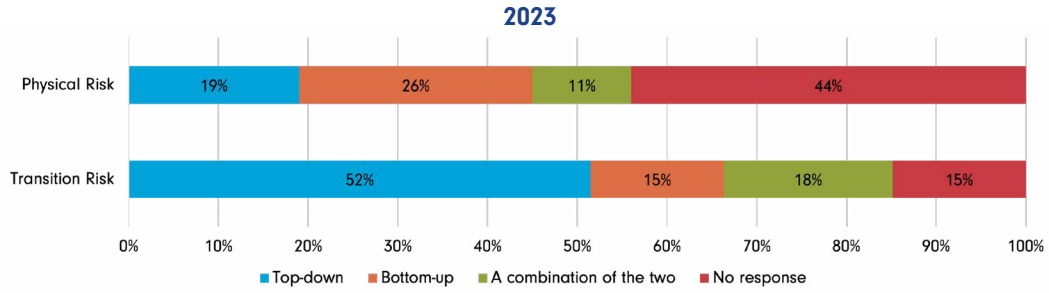
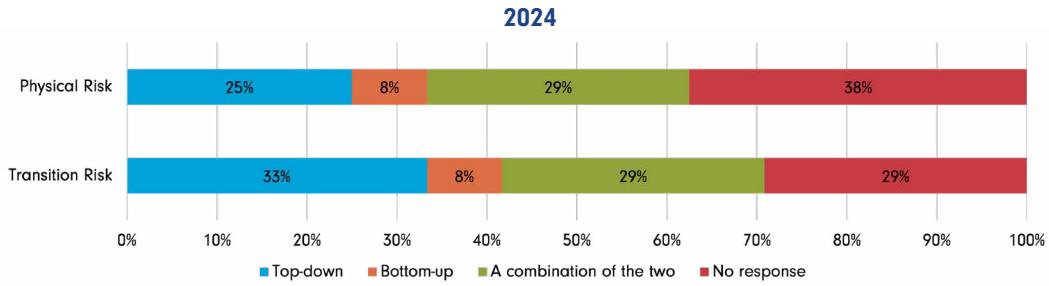


Figure 7: Top-down vs. Bottom-up Approaches to Climate Scenario Analysis (2024)



Banks were asked what kind of approach they take to calibration, and their responses, as well as working group discussions, indicate that a combination approach is used.

KEY TAKEAWAY 6: Banks are increasingly using a combination of expert judgment and data-driven assessment to calibrate climate risk shocks.

ISDA has observed an increase in the use of a solely data-driven assessment and a combination assessment in Phase 3.

As shown in Figures 8 and 9, for transition risk, 54% of respondents in 2024 indicated they use a combined approach, compared to 44% in 2023. In Phase 3, 8% indicated a data-driven assessment, compared to 7% in 2023.

For physical risk, 46% of respondents in 2024 indicated they use a combined approach, compared to 18% in 2023. In 2024, 8% indicated a data-driven assessment compared to none in 2023.

Figure 8: Calibration of Shocks for Top-down Approach (2023)

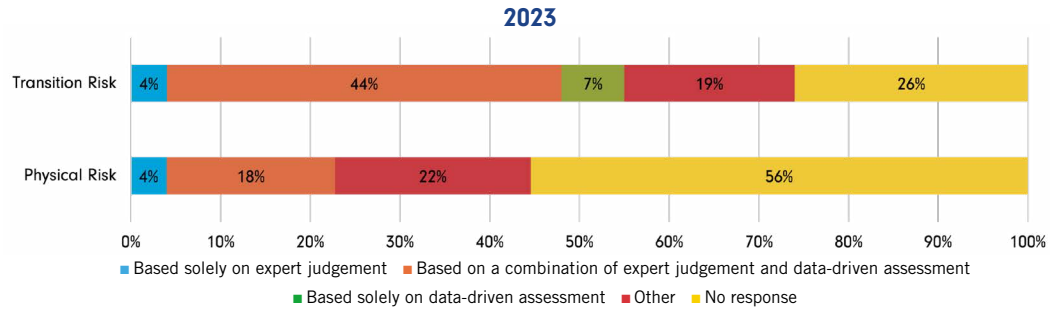
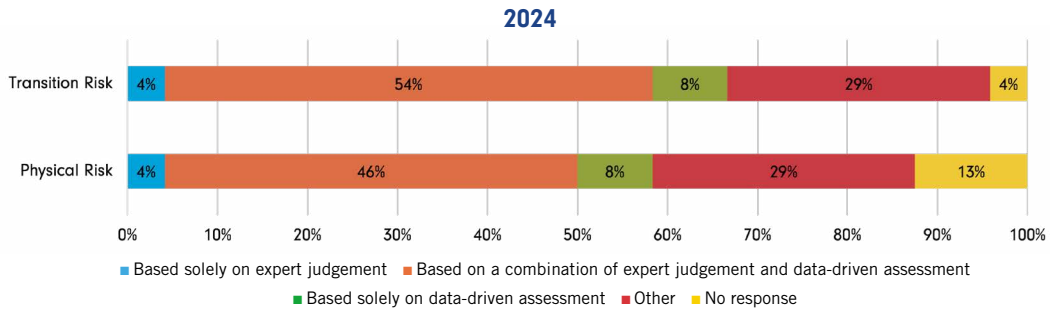


Figure 9: Calibration of Shocks for Top-down Approach (2024)



Survey Results: Applications

Overall, responses to this section indicated the following results:

7. Climate risk in the trading book is increasingly being assessed as part of ICAAPs and ILAAPs. Banks have indicated they do so at a high level rather than at a granular level, by asset or material risk type;
8. Disclosure of trading book climate scenario analysis is limited;
9. Further analysis is needed before banks can use climate scenario analysis in the trading book for bank strategy;
10. The primary use case for climate scenario analysis in the trading book continues to be regulatory compliance.

There was a notable increase in banks' assessment of climate risk in the trading book at a high level

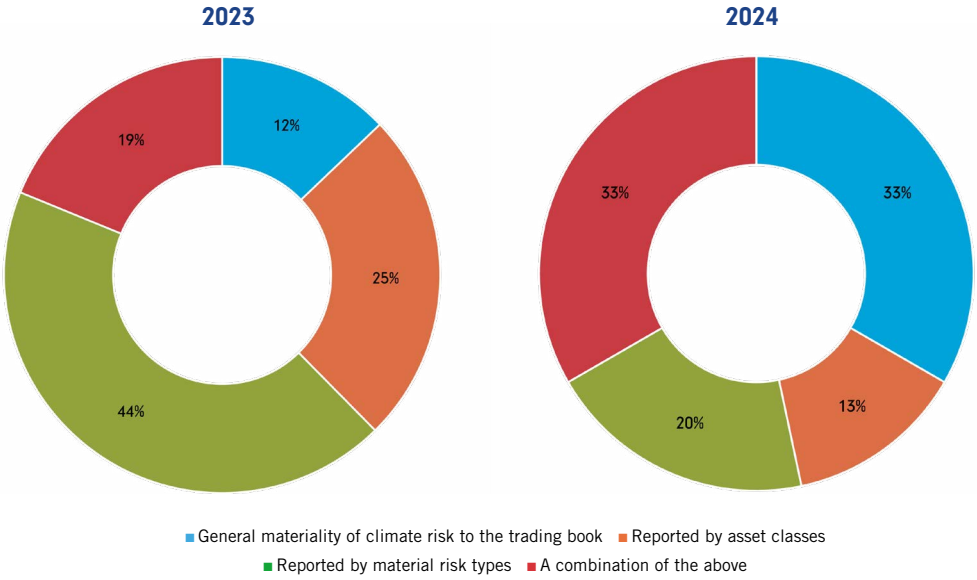
Banks were asked whether climate scenario analysis featured in their ICAAPs and ILAAPs, and at what level of granularity.

KEY TAKEAWAY 7: Climate risk in the trading book is increasingly being assessed as part of ICAAPs and ILAAPs. Banks have indicated they do so at a high level rather than a granular level, by asset or material risk type.

Although a similar number of banks indicated they assess climate risk qualitatively and quantitatively in the 2023 and 2024 surveys, there was a notable increase in banks' assessment of climate risk in the trading book at a high level rather than at a granular asset or material risk type level.

As shown in Figure 10, a comparison of the 2023 and 2024 surveys shows a smaller proportion of respondents that included analysis in ICAAP/ILAAP indicate they report climate risk in the trading book at a granular level. In 2024, 20% of respondents indicated they assess climate risk by material risk type (eg, market risk or counterparty credit risk), compared to 44% in 2023. On the other hand, a larger proportion of respondents indicate a high-level assessment of climate risk in 2024 (33%) than in 2023 (12%).

Figure 10: 2023 vs. 2024 Comparison of Granularity of ICAAP/ILAAP Reporting of Climate Scenario Analysis



Banks were also asked whether the results of climate scenario analysis were reported.

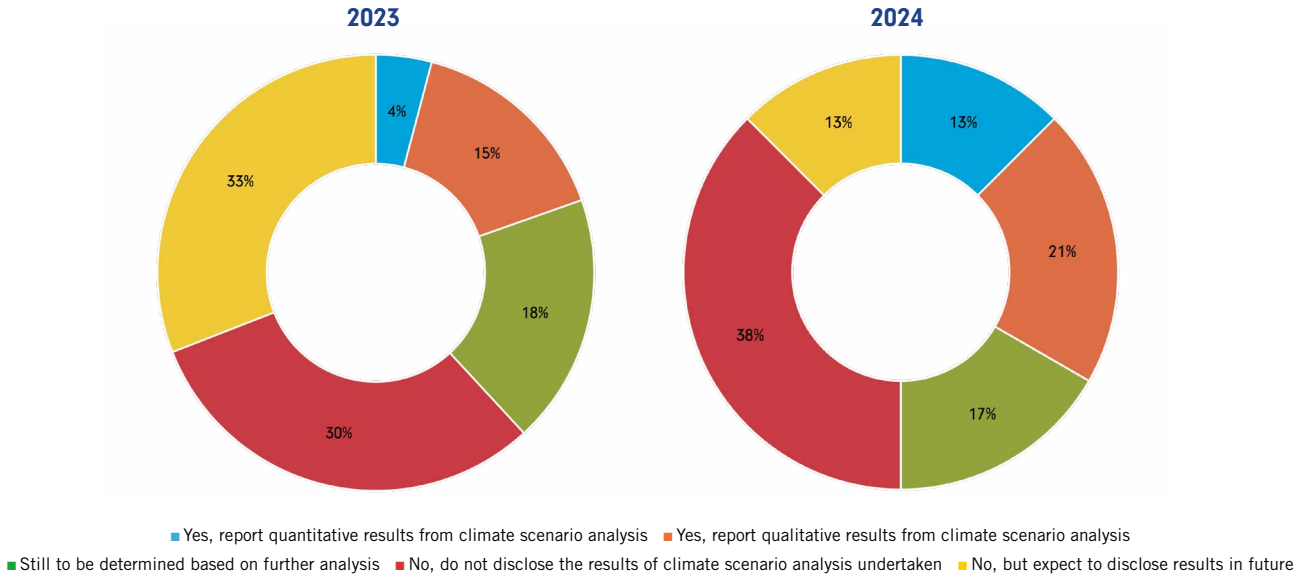
The updated Phase 3 results indicate banks do not disclose the results of climate scenario analysis. This is most likely due to reporting currently being focused on credit risk, which is perceived to be the most materially impacted by climate risk

KEY TAKEAWAY 8: Disclosure of trading book climate scenario analysis is limited.

The updated Phase 3 results indicate banks do not disclose the results of climate scenario analysis. This is most likely due to reporting currently being focused on credit risk, which is perceived to be the most materially impacted by climate risk.

As indicated in Figure 11, a greater proportion of total survey respondents in 2024 (38%) indicated that they do not disclose the results of the climate scenario analysis undertaken compared to 2023 (30%). Furthermore, a smaller proportion of total survey respondents in 2024 (13%) indicated they don't do so currently but expect to disclosure results in future, compared to 2023 (33%).

Figure 11: 2023 vs. 2024 Reported Aspects of Trading Book Climate Scenario Analysis in Disclosures

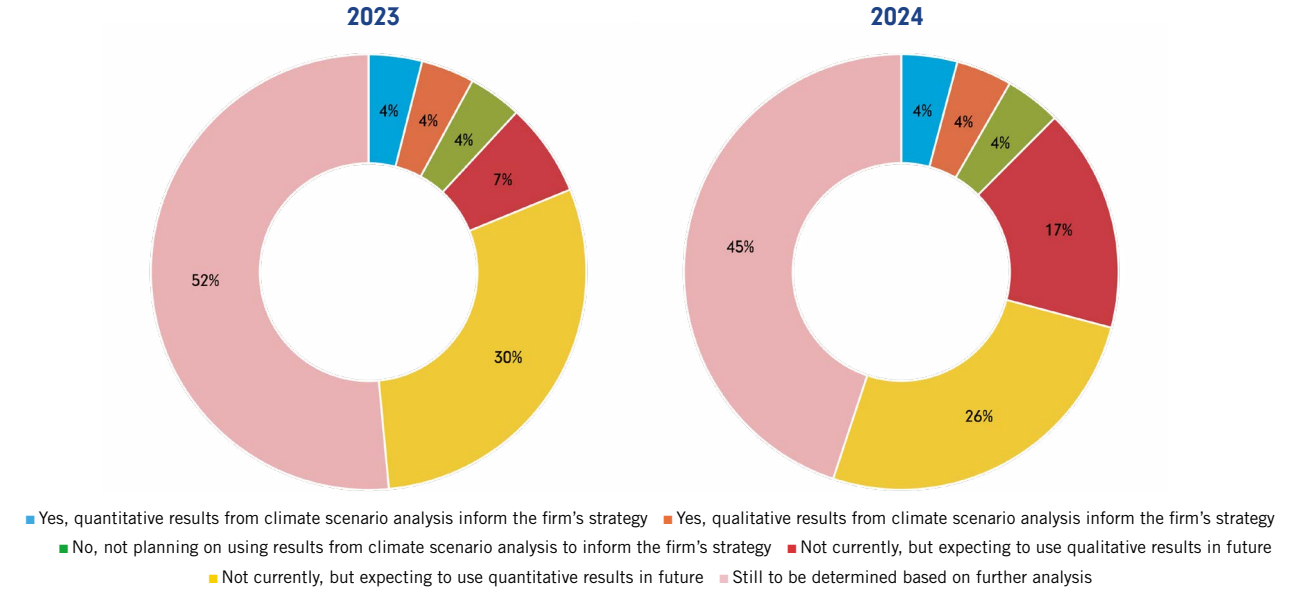


Many banks need to conduct more analysis before using climate scenario analysis to inform strategy.

KEY TAKEAWAY 9: Further analysis is needed before banks can use climate scenario analysis in the trading book for bank strategy.

As shown in Figure 12, the overall results in 2024 are similar to those in 2023. In 2024, 4% of respondents indicated they use quantitative results to inform strategy, compared to none in 2023. In 2024, a greater proportion (17%) do not use qualitative results but expect to do so in the future, compared to 2023 (7%). In 2024, it remains the case that a large proportion of respondents (45%) need to conduct further analysis to determine if climate scenario analysis in the trading book will inform strategy.

Figure 12: Climate Scenario Analysis in Informing Strategy, 2023 vs 2024



Banks were asked which uses cases were relevant for climate scenario analysis in the trading book.

KEY TAKEAWAY 10: The primary use case for climate scenario analysis in the trading book continues to be regulatory compliance.

Banks primarily conduct climate scenario analysis for regulatory compliance and internal risk management purposes, as part of both their current and expected future states. Banks have also indicated plans to integrate their scenario analysis results in disclosures, strategy and pricing in the future, but data and model sophistication are constraining this.

Banks primarily conduct climate scenario analysis for regulatory compliance and internal risk management purposes, as part of both their current and expected future states.

Figures 13 and 14 show that 83% of respondents in 2024 chose regulatory compliance as the primary use case for climate scenario analysis for trading book, compared to 56% in 2023. Almost all respondents indicated they plan to consider it in the future.

Furthermore, risk measurement and management were the second most popular current use case with 74% of respondents in 2024, compared to 56% in 2023. Respondents indicated that disclosures and strategy and pricing are in the early stages of adoption.

Figure 13: Use Cases for Climate Scenario Analysis (2023)

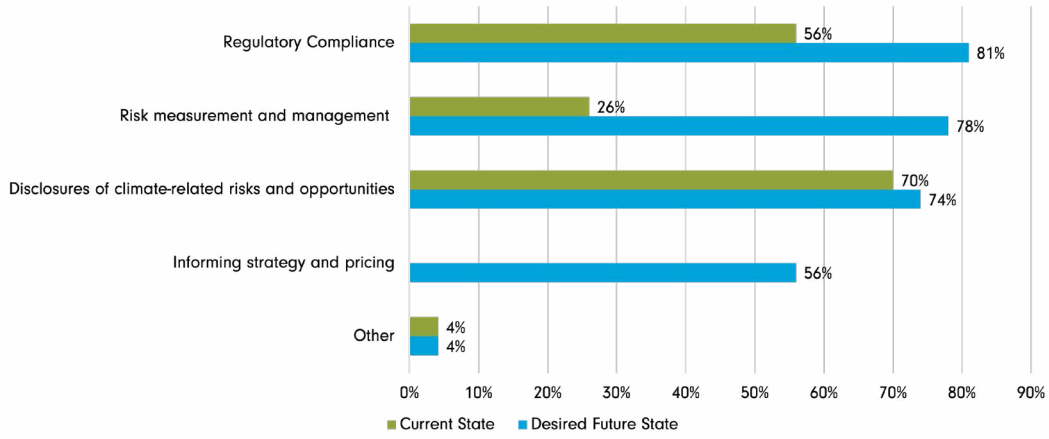
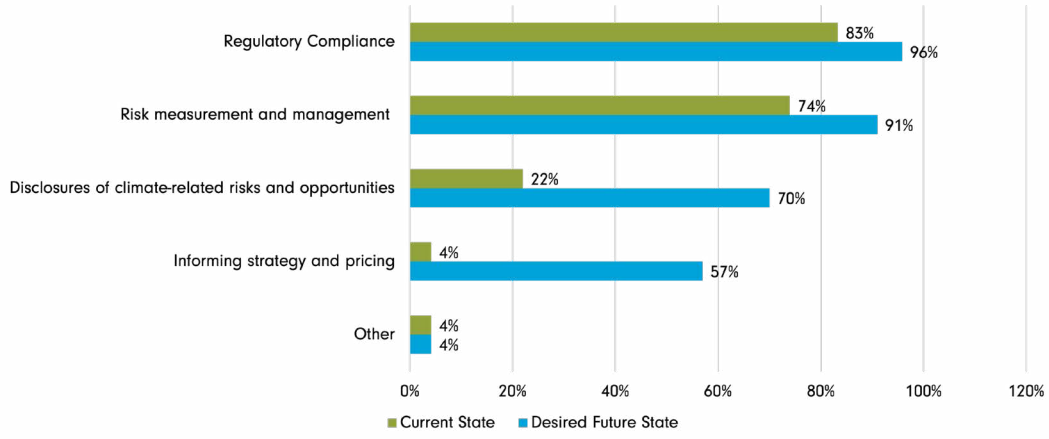


Figure 14: Use Cases for Climate Scenario Analysis (2024)



3. PHASE 3 EXPANSION OF MARKET RISK FACTOR SHOCKS

The second objective of Phase 3 was to expand the set of market risk factor shocks and macroeconomic shocks to new geographies, specifically for the transition risk scenario that was designed as part of Phase 2. The expanded scenario will support banks in their own climate scenario analysis.

In Phase 2, ISDA developed macroeconomic and market risk shocks for the UK, the US, the EU, Japan, Brazil and India. The working group proposed that Phase 3 would cover four new geographies – South Africa, China, Australia, and Canada. The group also decided that consistency with Phase 2 was important, so it agreed to focus on the same asset classes (government bonds, swaps, credit spreads, equities, commodities and FX) and the same liquidity horizons (one-day, 10-day, three-month, and one-year horizons), restating that these are the most appropriate for assessing shocks for the trading book.

The transition risk scenario developed in Phase 2 entails a sudden and dramatic increase in the price of carbon. In this scenario, coordinated action by multiple countries to introduce a carbon tax on production leads to a simultaneous, instantaneous increase in the price of carbon to $200 per ton

To generate market risk factor shocks for an expanded set of countries, ISDA followed the same approach as in Phase 2. This also ensured consistency with the conceptual framework developed in Phase 1. In particular, a set of country-specific macroeconomic shocks was developed for these new economies, consistent with the scenario narrative in Phase 2. Those macroeconomic shocks were used as inputs into a series of market risk factor expansion models to produce a set of market risk factor shocks.

Each of these stages and the associated results are explained in the sections that follow.

3.1. Scenario Narrative and Phase 3 Assumptions

The transition risk scenario developed in Phase 2 entails a sudden and dramatic increase in the price of carbon. In this scenario, coordinated action by multiple countries to introduce a carbon tax on production leads to a simultaneous, instantaneous increase in the price of carbon to $200 per ton. The carbon tax is assumed to be imposed on firm production, so the effect of the carbon tax is captured as a wedge between producer prices and consumer prices, with consumer prices rising while the price of raw materials remains stable.

As the instantaneous additional tax is imposed on firm production, this leads to a rise in unit input costs , which are passed on to the consumer, pushing up inflation. At the same time, output falls due to reduced demand for goods from highly polluting sectors. The specific impact on macroeconomic variables in each country are described in the results section of this paper.

Based on this narrative, the assumption is that there is no impact on long-term inflation expectations, or on long-term growth rates as the shock is a one-off, permanent shock to the level of carbon taxes, leading to temporary shocks to inflation, growth and interest rates.

A key underlying assumption is that central bank inflation targets remain credible. Given the size of the shocks in the scenario, this seems reasonable. The assumption that central bank inflation targets remain credible could be violated, for example if the shocks were extremely large, or if there was a series of large shocks over an extended period. However, given the narrative and calibration, these possibilities were not explored in the short-term transition risk scenario.

3.2. Macroeconomic Shocks

To generate the expanded set of macroeconomic shocks for the transition scenario, ISDA leveraged the agent-based model (ABM) developed in Phase 2, which focused on obtaining core macroeconomic results for developed markets. By focusing on modeling the economic behavior of different agents in response to climate shocks, the ABM approach enabled the development of forward-looking scenarios that are not simply a repeat of the past. Those forward-looking ABM scenarios were then linked to other countries by establishing historical relationships between the macroeconomic data of the ABM-modelled countries and those of the newly added geographies. This was achieved through regression techniques, allowing stressed macroeconomic projections to be generated for the expanded set of countries dependent on the forecasts from the Phase 2 ABM economies.

The output of the macro model in Phase 3 was consistent in magnitude and direction to the Phase 2 outputs. Declines in GDP were observed across all regions, flattening out in the ninth month as the economies begin to adapt to the new equilibrium. This is consistent with the scenario narrative.

Interest rates and inflation rise substantially, reflecting a monetary policy response to increases in the factor input costs and prices associated with the carbon tax. In terms of relative severity among the Phase 3 economies, South Africa and Australia were the most impacted, reflecting historical volatility and relative dependence on carbon-intensive industries.

Figure 15: Phase 2 and 3 GDP Forecasts

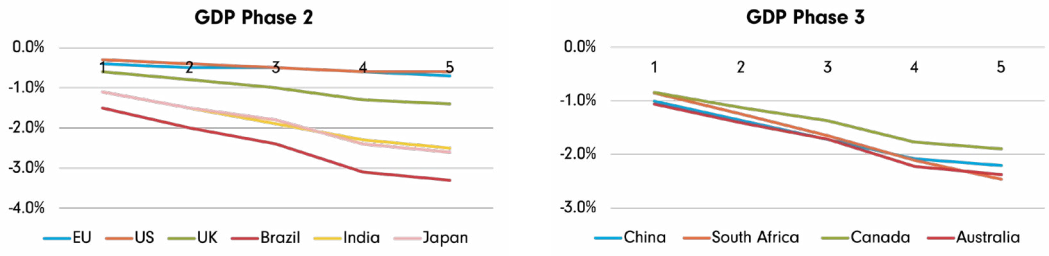


Figure 16: Phase 2 and 3 Inflation Forecasts

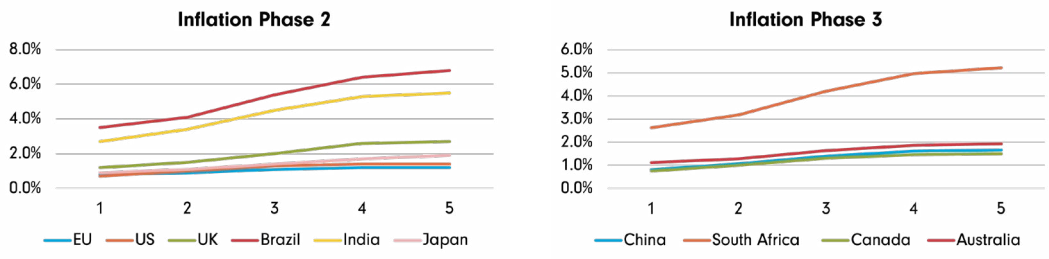
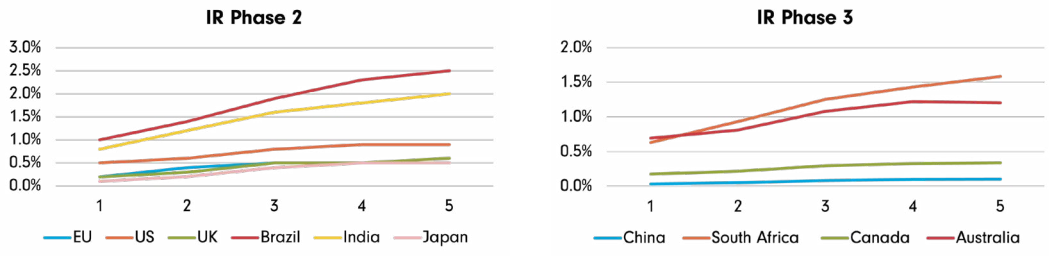


Figure 17: Phase 2 and 3 Interest Rate Forecasts



3.3. Market Risk Factor Shocks

A crucial part of the conceptual framework was translating the climate-adjusted macroeconomic shocks into market risk shocks. For Phase 3, a range of expansion models were used to develop market risk factors for each asset class. The models were built on the foundations of Phase 2, with some changes, notably for equities and swaps in response to working group feedback to ensure more transparent links between the macroeconomic factors and the market risk factor shocks. The detailed methodology and equations for each of the models can be found in the Appendix. The mapping of models to market risk factors is set out in Table 1.

Table 1: Market Risk Factors by Model Type

Market Risk Factor	Model	Key Macroeconomic Drivers
Equities	Gordon Growth Model	Interest rate, GDP
Government Yield Curves	Hull White Model	Interest rate
Interest Rate Swap Curves	Hull White Model	Interest rate
Breakeven Inflation	Hull White Model	Interest rate
Credit Spreads	CDS Bootstrapping Model	Interest rate, GDP
FX	Uncovered Interest Parity	Interest rate
Commodities	Regression on ABM Macroeconomic Outputs	Macroeconomic Data

Selection Process

Banks were asked to provide input and suggestions on the scope of those market risk factor shocks that they consider as most relevant and useful. Banks submitted market risk factor shock suggestions across a range of asset classes and countries.

To determine the most relevant and useful shocks, a categorization and scoring process was introduced. First, all submissions were separated by asset class to ensure sufficient representation across asset classes. Then, a process was designed to score and weight each market risk factor shock suggestion within their asset class based on four categories: popularity (40%), data availability (25%), modeling time (25%) and representativeness (10%). Each category would receive a score of 1-3, with 1 being the least ideal and 3 being the most ideal. After scoring within asset class, the submitted market risk factor shocks were reaggregated into one list, and the shocks with the highest scores were selected for calibration.

These chosen shocks spanned credit, equity, rates, commodities and FX. The preliminary list of market risk factor shock suggestions was presented to the working group for further feedback. The working group emphasized a further interest in Asian sectors across equities and credit.

To incorporate the working group's feedback, Asian sectors – power, air transport, mining and quarrying, manufacture of chemical products and land transport – across equities and credit were included in the list of market risk factor shocks for calibration. To ensure consistency and alignment between geographies, shocks for the same sectors where produced for Asia, the US and the EU (the equity and credit shocks were produced for the EU as part of Phase 2)[6].

[6] See next section for full list of market risk factors

Crowdsourcing Process

Once the set of modeled results for the selected set of market risk shocks had been produced, they were distributed to the working group for the crowdsourcing process to be conducted. The crowdsourcing process allows the banks to provide their opinion on the size and shape of the modeled shocks. Climate modeling is nascent and modeling climate shocks is further complicated by the lack of historical precedent. Therefore, a key part of constructing the final set of market risk shocks was including this expert judgment provided by the ISDA working group.

The expert judgment was gathered through a survey process and then overlaid onto the pure modeled shocks to produce the final set of market risk factor shocks set out in the next section. The crowdsourcing aspect of the scenario analysis was an integral part of the process. The introduction of expert views mitigated against the non-linearities and structural changes expected by climate change. It also reduced model uncertainty, as well as acting as a further validatory check on the set of shocks produced and the suitability of the model methodologies chosen.

Banks submitted quantitative and qualitative responses to the modeled market risk factor shocks. To aggregate the submissions from the working group, individual submissions for each market risk factor shock were organized and the modeled output was added to the list. From this list of working group submissions and the modeling output, the median was taken. The median was then rounded to the nearest interval of 5, and this value was treated as the final market risk factor shock.

3.4. Results

This section includes the complete list of market risk factors from Phases 2 and 3 of the project, after the crowdsourcing process had been applied. The descriptions focus on the Phase 3 shocks but relate these to the Phase 2 numbers, where relevant. The shocks for each asset class are discussed in turn.

The shocks with a white background are Phase 2 shocks, while the shocks with a green background are Phase 3 shocks.

Equities

In Phase 3, equity shocks were produced at the country level for the new economies, and the sectors were expanded to cover the US and Asia. The results show substantial declines in equity prices across all indices and sectors in the transition risk scenario. This reflects the macroeconomic impact of the carbon tax pushing up inflation and interest rates, leading to reduced profits and valuations and lowering GDP.

At the sector level, the effects are particularly pronounced for the carbon-intensive sectors selected by the ISDA working group for this exercise. These include air transport, electricity, mining and quarrying, manufacturing of chemicals and land transport. These sectors are particularly vulnerable to the carbon tax shock and experienced large equity price declines, with the mining and quarrying sector suffering the largest drop. The finance sector, which is new for Phase 3, shows a smaller drop over the period, reflecting the sector's lower exposure to a carbon tax.

The substantial negative impact on carbon-intensive sectors supports the overall transition risk narrative. Countries exporting raw materials that are significant for resourcing transition technologies may experience a less severe impact on their equity indices.

Figure 18: Transition Risk Shocks for Equities

Asset Class	Region	Sector	Risk factor	ISDA Proposed Shocks			
				1 d	10 day	3 m	1Y
Equities (percentage change)	Europe	Air Transport		-10%	-20%	-25%	-30%
		Electricity		-10%	-20%	-25%	-30%
		Mining & Quarrying		-15%	-25%	-30%	-35%
		Publishing Activities		0%	-5%	-10%	-10%
		Manufacture of Chem/Chem Prods		-10%	-20%	-25%	-30%
		Land Transport		-10%	-20%	-25%	-30%
		Finance	Thompson Reuters - Europe Index	-5%	-5%	-15%	-15%
		Index	Eurostoxx50	-5%	-10%	-15%	-20%
	US	Air Transport	Thompson Reuters - North America Index	-10%	-15%	-20%	-30%
		Electricity		-10%	-15%	-20%	-30%
		Mining & Quarrying		-15%	-20%	-25%	-40%
		Manufacture of Chem/Chem Prods		-10%	-15%	-20%	-30%
		Land Transport		-10%	-15%	-20%	-30%
		Finance		-5%	-10%	-15%	-20%
		Index	S&P500	-5%	-10%	-10%	-25%
	Asia	Air Transport	Thompson Reuters - Asia Index	-15%	-20%	-30%	-35%
		Electricity		-15%	-25%	-35%	-35%
		Mining & Quarrying		-20%	-50%	-60%	-60%
		Manufacture of Chem/Chem Prods		-10%	-20%	-30%	-35%
		Land Transport		-10%	-20%	-30%	-35%
		Finance		-10%	-15%	-25%	-20%
	China	Index	SSC 100	-5%	-10%	-15%	-20%
	Japan	Index	NIKKEI225	-5%	-10%	-15%	-20%
	UK	Index	FTSE100	-5%	-10%	-10%	-20%
	South Africa	Index	FTSE/JSE Top 40	-10%	-15%	-20%	-30%
	Canada	Index	S&P/TSX 60	-5%	-10%	-15%	-25%
	Australia	Index	S&P/ASX200	-5%	-10%	-15%	-25%

Credit

Credit spreads widen across all regions and sectors in the scenario, consistent with the transition risk shock increasing the probability of company defaults across the economy. This reflects the macroeconomic impact of the carbon tax lowering GDP, while also pushing up inflation and interest rates, which led to reduced profits and valuations. All carbon-intensive sectors see widening spreads, with the largest increase in the mining and quarrying sector, consistent with this sector being particularly affected and experiencing the largest fall in equity prices.

Figure 19: Transition Risk Shocks for Credit

Asset Class	Region	Sector	Risk factor	ISDA Proposed Shocks			
				1 d	10 day	3 m	1Y
Credit (absolute spread change, in basis points)	Europe	Air Transport	IG - ITRAXX EU	20	20	70	110
		Electricity		20	30	80	120
		Mining & Quarrying		25	50	100	130
		Manufacture of Chem/Chem Prods		25	30	80	120
		Land Transport		20	20	80	120
		Finance	IG - ITRAXX EU	15	20	40	50
	US	Air Transport	IG - CDX NA	20	25	50	85
		Electricity		20	30	55	85
		Mining & Quarrying		35	45	80	120
		Manufacture of Chem/Chem Prods		25	30	55	85
		Land Transport		20	25	55	85
		Finance		15	20	40	50
	Asia	Air Transport	IG-ITRAXX ASIA	20	25	65	100
		Electricity		20	30	75	100
		Mining & Quarrying		30	60	95	130
		Manufacture of Chem/Chem Prods		25	30	70	110
		Land Transport		20	25	70	100
		Finance		15	25	50	55
	UK/USD		USD 5Y CDS on UK	10	20	40	75

Rates

In the transition risk scenario, yield curves rise across countries and maturities for both government bonds and swaps. The rises are associated with central bank interest rate increases in response to higher inflation, fueled by the introduction of the carbon tax. As central banks raise rates, investors seek higher returns to match the new interest rate environment. The increases in yield curves are smaller at longer maturities, reflecting the temporary nature of the inflation shock. The increases in yield curves are largest for Brazil, South Africa and India, consistent with greater historical interest rate volatility in these countries. The increases in swap curve rates are consistent with the rise in risk-free rates.

Breakeven inflation curves also rise in the UK and the US. The rises in the US were slightly larger, consistent with the larger increase in nominal yield curves in the scenario. The increases in breakeven inflation rates were larger than the increases in nominal rates, consistent with falls in real rates driven by weaker demand.

Figure 20: Transition Risk Shocks for Rates

Asset Class	Region	Sector		ISDA Proposed Shocks			
				1 d	10 day	3 m	1Y
Rates (absolute change, in basis points)	Asia	Government	INDIA GOV 1D	35	90	120	190
		Government	INDIA GOV 6M	30	80	110	180
		Government	INDIA GOV 1Y	25	70	100	170
		Government	INDIA GOV 5Y	20	60	90	160
		Government	INDIA GOV 10Y	15	50	80	150
		Government	INDIA GOV 20Y	10	40	70	140
	Europe	Government	GER GOV 1D	30	50	80	90
		Government	GER GOV 6M	20	40	70	80
		Government	GER GOV 1Y	10	30	60	70
		Government	GER GOV 5Y	10	20	50	60
		Government	GER GOV 10Y	5	10	40	50
		Government	GER GOV 20Y	5	5	30	40
		Swap	EUR SW 1D	25	60	80	100
		Swap	EUR SW 6M	20	50	70	90
		Swap	EUR SW 1Y	15	40	60	80
		Swap	EUR SW 5Y	10	30	50	70
		Swap	EUR SW 10Y	10	20	40	60
		Swap	EUR SW 20Y	5	15	30	50

continued on next page

continued from previous page

Asset Class	Region	Sector		ISDA Proposed Shocks			
				1 d	10 day	3 m	1Y
Rates (absolute change, in basis points)	UK	Government	GBP GOV 1D	30	60	80	80
		Government	GBP GOV 6M	20	50	70	70
		Government	GBP GOV 1Y	10	40	50	60
		Government	GBP GOV 5Y	10	30	40	50
		Government	GBP GOV 10Y	5	20	30	40
		Government	GBP GOV 20Y	5	10	20	30
		Swap	GBP SW 1D	30	70	80	90
		Swap	GBP SW 6M	25	60	70	80
		Swap	GBP SW 1Y	20	50	60	70
		Swap	GBP SW 5Y	10	40	50	60
		Swap	GBP SW 10Y	10	30	40	50
		Swap	GBP SW 20Y	5	20	30	40
		Breakeven Inflation	GB 1D	45	55	70	95
		Breakeven Inflation	GB 6M	45	50	65	90
		Breakeven Inflation	GB 1Y	35	40	50	90
		Breakeven Inflation	GB 5Y	15	45	40	85
		Breakeven Inflation	GB 10Y	15	35	35	70
		Breakeven Inflation	GB 20Y	15	20	25	50
	US	Government	USD GOV 1D	30	70	80	160
		Government	USD GOV 6M	25	60	70	150
		Government	USD GOV 1Y	20	50	60	140
		Government	USD GOV 5Y	10	40	50	130
		Government	USD GOV 10Y	10	30	40	120
		Government	USD GOV 20Y	5	20	30	110
		Swap	USD SW 1D	30	60	80	170
		Swap	USD SW 6M	25	50	70	160
		Swap	USD SW 1Y	20	40	80	150
		Swap	USD SW 5Y	10	30	70	140
		Swap	USD SW 10Y	10	20	60	130
		Swap	USD SW 20Y	5	10	50	120

continued on next page

continued from previous page

Asset Class	Region	Sector		ISDA Proposed Shocks			
				1 d	10 day	3 m	1Y
Rates (absolute change, in basis points)	US	Breakeven Inflation	US 1D	50	60	75	115
		Breakeven Inflation	US 6M	50	35	70	110
		Breakeven Inflation	US 1Y	45	30	60	105
		Breakeven Inflation	US 5Y	40	45	50	80
		Breakeven Inflation	US 10Y	30	35	45	60
		Breakeven Inflation	US 20Y	15	20	25	50
	Other	Government	BRL GOV 1D	35	90	120	190
		Government	BRL GOV 6M	30	80	110	180
		Government	BRL GOV 1Y	25	70	100	170
		Government	BRL GOV 5Y	20	60	90	160
		Government	BRL GOV 10Y	15	50	80	150
		Government	BRL GOV 20Y	10	40	70	140
	China	Government	CNY GOV 1D	15	25	30	35
		Government	CNY GOV 6M	15	25	30	35
		Government	CNY GOV 1Y	10	20	25	30
		Government	CNY GOV 5Y	5	10	10	15
		Government	CNY GOV 10Y	10	10	10	10
		Government	CNY GOV 20Y	5	5	5	5
		Swap	CNY SW 1D	15	25	30	35
		Swap	CNY SW 6M	15	25	30	35
		Swap	CNY SW 1Y	10	20	25	30
		Swap	CNY SW 5Y	5	10	10	15
		Swap	CNY SW 10Y	10	10	10	10
		Finance		15	25	50	55
	South Africa	Government	ZAR GOV 1D	40	60	75	95
		Government	ZAR GOV 6M	35	55	75	95
		Government	ZAR GOV 1Y	40	60	85	105
		Government	ZAR GOV 5Y	30	50	80	100
		Government	ZAR GOV 10Y	20	35	50	60
		Government	ZAR GOV 20Y	15	20	30	40

continued on next page

continued from previous page

Asset Class	Region	Sector		ISDA Proposed Shocks			
				1 d	10 day	3 m	1Y
Rates (absolute change, in basis points)	South Africa	Swap	ZAR SW 1D	40	60	80	100
		Swap	ZAR SW 6M	40	60	75	100
		Swap	ZAR SW 1Y	40	65	85	110
		Swap	ZAR SW 5Y	45	70	90	125
		Swap	ZAR SW 10Y	25	60	80	115
		Swap	ZAR SW 20Y	25	35	50	80
	Canada	Government	CAD GOV 1D	20	25	35	40
		Government	CAD GOV 6M	20	25	30	35
		Government	CAD GOV 1Y	20	25	35	40
		Government	CAD GOV 5Y	10	10	15	15
		Government	CAD GOV 10Y	5	5	15	15
		Government	CAD GOV 20Y	10	10	10	10
		Swap	CAD SW 1D	25	25	40	40
		Swap	CAD SW 6M	20	25	35	45
		Swap	CAD SW 1Y	25	30	45	50
		Swap	CAD SW 5Y	15	20	25	30
		Swap	CAD SW 10Y	10	10	15	20
		Swap	CAD SW 20Y	5	5	15	15
	Australia	Government	AUD GOV 1D	30	20	25	65
		Government	AUD GOV 6M	30	25	55	65
		Government	AUD GOV 1Y	35	40	65	75
		Government	AUD GOV 5Y	30	45	60	65
		Government	AUD GOV 10Y	20	30	40	45
		Government	AUD GOV 20Y	10	10	20	20
		Swap	AUD SW 1D	30	20	60	70
		Swap	AUD SW 6M	35	25	60	75
		Swap	AUD SW 1Y	35	40	65	80
		Swap	AUD SW 5Y	40	45	65	80
		Swap	AUD SW 10Y	25	30	50	65
		Swap	AUD SW 20Y	10	10	20	25

FX

The US dollar appreciated in this scenario. This appreciation was highest against the currencies of India, Brazil and China. The appreciation was consistent with relative interest rate shocks, reinforced by risk aversion against emerging market currencies.

Figure 21: Transition Risk Shocks for FX

Asset Class	Region	Sector	Risk factor	ISDA Proposed Shocks			
				1 d	10 day	3 m	1Y
FX (percentage change)	India		USDINR	-5%	-10%	-15%	-20%
	Japan		USDJPY	0%	0%	0%	0%
	Europe		USDEUR	0%	0%	0%	0%
	UK		USDGDP	0%	0%	0%	0%
	Other		USDBRL	-5%	-10%	-15%	-20%
	China		USDCNY	-5%	-5%	-5%	-5%
	South Africa		USDZAR	-5%	-5%	-10%	-5%
	Canada		USDCAD	-5%	-5%	-10%	-5%
	Australia		USDAUD	-5%	-5%	-5%	-10%

Commodities

In Phase 2, gold prices increased as investors perceived this as a 'flight to safety' sector in economic turmoil. Other commodity prices fell as GDP declined, causing demand to fall. There was a large impact on oil and coal prices, as these are adversely affected by the carbon tax.

Working group members provided a wide variety of views on the Phase 3 commodities shocks. Discussions explored whether, in a transition risk narrative, commodities shocks would be negative or positive.

Some working group members noted that since certain transition metals are included, such as cobalt and copper, as well as transition fuels, such as natural gas, these commodities would experience an increase in price levels due to an increase in relative demand for transition materials. Furthermore, other working group members suggested that given the overall narrative and increase in inflation, it may be consistent to see that the price of commodities such as steel would also increase, given steel producers would face an increase in input costs under this scenario.

There were extensive discussions about the mix of relative price impacts leading to higher prices, alongside the impact of falling global demand associated with lower prices, and which effect would dominate for each of the commodities being considered.

The final Phase 3 shocks show increases in prices for cobalt and copper, reflecting increased demand for transition metals. Steel also saw positive shocks associated with increases in the price of its factor inputs, including iron ore and coal, and the carbon tax more than offsetting the negative impact of reduced global demand. Natural gas received a positive shock, reflecting the balance of large positive relative demand impacts being partially offset by some negative impacts from reduced global demand. This reflects natural gas being considered as a transition fuel.

Figure 22: Transition Risk Shocks for Commodities

Asset Class	Region	Sector	Risk factor	ISDA Proposed Shocks			
				1 d	10 day	3 m	1Y
Commodities (percentage change)	Global		GOLD	5%	10%	15%	20%
			CBOT CORN	-5%	-5%	-5%	-5%
			COAL PRICE	-10%	-20%	-30%	-40%
			WTI CRUDE	-5%	-10%	-20%	-30%
	Global		STEEL	0%	5%	5%	20%
			COBALT	5%	10%	20%	20%
			COPPER	5%	10%	15%	20%
			NATURAL GAS	5%	5%	10%	25%

4. CONCLUSION AND NEXT STEPS

Overall, the Phase 3 survey results across design, modeling and applications indicate that climate risk scenario analysis is increasingly being put into practice.

On the narrative front, the results indicate there is strong interest in ISDA's short-term scenarios alongside the NGFS scenarios. Banks have expanded their capabilities to consider a broader range of market risk assets such as FX, interest rates and equities, in addition to a continuing interest in credit. Furthermore, there is continued reliance on expert judgment in modeling, but there is also an overall shift to a combined top-down and bottom up-approach, suggesting increased sector- and asset-level granularity in modeling.

The expansion of market risk factors in Phase 3 has produced a more complete set of market risk shocks for banks to draw on for their climate scenario analysis. The range of shocks now covers China, Australia, Canada and South Africa, in addition to the Phase 2 countries (the US, the EU, the UK, Japan, India and Brazil).

The market risk shocks were produced for asset classes consistent with Phase 2 and include government bonds, swaps, equities, credit spreads, commodities and FX. The approach was also consistent with Phase 2, using the transition scenario narrative. A macroeconomic model was used to translate that narrative into a set of country-specific macroeconomic shocks, and a suite of expansion models was used to map those shocks into market risk shocks.

The market risk shocks produced in Phase 3 showed consistency with the results obtained in Phase 2, aligning in both magnitude and direction. Notably, Phase 3 shocks resulted in a negative impact across all assessed areas, aside from some commodity assets that are perceived as transition fuels.

Acknowledgements

Deloitte was commissioned by ISDA to support the production of this paper. Deloitte supported by providing resources and analysis to facilitate working group discussions of the Phase 3 survey and the Phase 3 expansion of market risk factor shocks.

The United Nations Environment Programme Finance Initiative was consulted throughout the process and ISDA had the benefit of providing updates to its working group to solicit and incorporate feedback.

5. APPENDIX: MODEL METHODOLOGIES

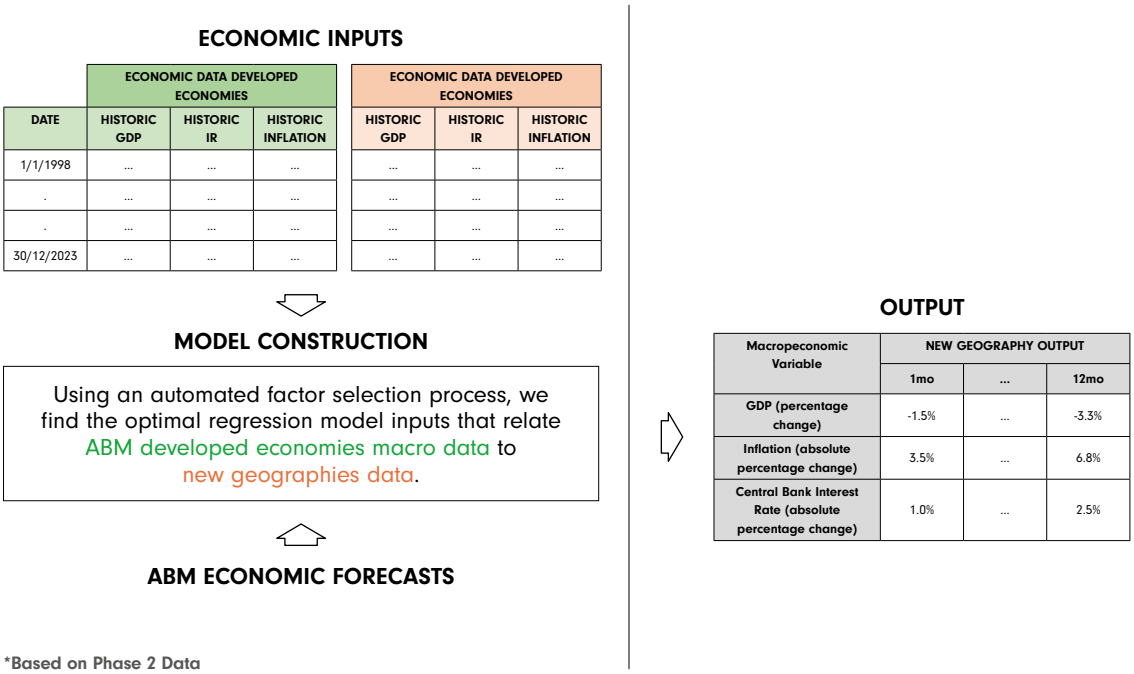
This appendix sets out the theoretical foundations of the models underpinning the results set out in this paper. It provides a concise overview of the core principles and concepts informing each model's structure and application within this research.

A.1. Macro Model

Following on from Phase 2, regression type models were chosen for establishing the historical relationship between the macroeconomic data from new geographies and the economic data from countries already modeled in the ABM.

These models were chosen for several reasons. First, regressions are relatively simple and widely understood, making the results easier to interpret and sense check. Second, regressions can effectively model linear relationships between variables, which is suitable for capturing the correlations between macroeconomic indicators (eg, GDP, inflation, interest rates). The macro model used a set of climate-adjusted shocks from the ABM model as inputs to produce a set of macroeconomic pathways over a one-year horizon.

Primarily, the model assumes linear relationships between macroeconomic indicators and stable historical correlations over time. The model's primary limitation is that the structure of the relationships between the developed economies of Phase 2 and the new economies of Phase 3 is invariant.



*Based on Phase 2 Data

A.2. Yield Curve Model

A Hull-White model was used to derive yield curves. It is an extension of the Vasicek model, with the ability to fit a term structure of interest rates. It assumes that short-term interest rates can be modeled as the realization of an Ornstein-Uhlenbeck mean-reverting stochastic process.

The model was used to simulate many different paths of future interest rates based on short rate shocks, here taken to be the risk-free rate shocks from the macroeconomic models. The future path of interest rates is modeled using two parameters that were calibrated to historical data: the speed of mean reversion and the volatility of the short rate. The volatility of the short rate was calculated directly from historical short rate data per economy. The speed of mean reversion is calculated using a least-squares fitting to historical yield curves, determining the value that best replicates past data. This ensures that the dynamics of the yield curve shocks conform to historical experiences, including previous financial crises. However, it did not necessarily limit the magnitude of the shocks to historical precedent, given that these shocks come from the macroeconomic model.

For each monthly time step in the macroeconomic model, the policy rate was used to calculate different paths of interest rates. The pre-determined values for the speed of mean reversion and volatility were used throughout for each relevant economy. From these, a yield curve is constructed that best fits the future paths of interest rates. By comparing these across different scenarios, the shocks to yield curves that result from the transition risk scenario were determined. The Hull-White model provided theoretical underpinning to the curves for: government bonds; swaps; and breakeven inflation. The output of the model was also used in the credit default swap (CDS) model, detailed in the next section.

The model assumes that the short rate follows a mean-reverting process. This means the model assumes that short-term interest rates tend to move back towards a long-term average over time. The Hull-White model assumes that the volatility of interest rates is constant over time. This is a simplification, as interest rate volatility can be observed to change in the real world. Like any model, the Hull-White model is a simplification of reality. It cannot capture all the complexities of the real-world interest rate market. For example, it may not accurately predict sudden, large spikes in interest rates.

INPUTS

SHORT RATE HISTORY (SONIA)

DATE	RATE
1-Sep-23	5.1852
.	.
.	.
3-Jan-18	0.4642
2-Jan-18	0.4622

REFERENCE DATE YIELD CURVE

TENOR	YIELD
0.5	5.52
.	.
.	.
24.5	3.91
25	3.9

MACRO-MODEL RATES OUTPUT ★

HORIZON	IR
1mo	0.20%
3mo	0.30%
6mo	0.50%
9mo	0.50%
12mo	0.60%

★ = Output from Macro-model (Random Forest)

HULL WHITE MODEL

Yield Curve Shock = f(short rate volatility, mean reversion of reference yield curve, short rate from macro model(per timestep))

*Based on Phase 2 Data

OUTPUTS

Market Risk Factor	ISDA Transition Risk			
	1mo	...	...	12mo
GBP GOV 1D	30	60	80	80
GBP GOV 6M	20	50	70	70
GBP GOV 1Y	10	40	50	60
GBP GOV 5Y	10	30	40	50
GBP GOV 10Y	5	20	30	40
GBP GOV 20Y	5	10	20	30

The shock is quantified as the difference between the yield curve at the reference date and the adjusted curve, which incorporates the rate delta from the macro model output.

COUNTRY	MEAN REVERSION	HISTORIC VOLATILITY
SA	0.2	0.6
CHN	0.8	0.4
CAN	0.6	0.45
AUS	0.2	0.5

A.3. Credit Model

A CDS is a derivatives product used for trading and risk management. Credit events can include complete default on payments, partial default, credit rating downgrades or widening credit spreads. To analyze a credit event, a Poisson process was used.

The Poisson process estimates the probability of default between two time points, conditional on survival until the initial time point. Hazard rates, or default intensities, were used in the Poisson process to model the likelihood of a credit event occurring. Survival probability is also required as a fundamental factor in pricing CDS contracts. The survival is the probability that no credit event will occur. Survival probability is not directly observable and must be implied from traded credit spreads in the market.

A bootstrapping algorithm was used to calculate survival probabilities from traded CDS spreads. The CDS spreads represent the market's view of credit risk. By using these spreads, the algorithm derives the survival probabilities, assuming a constant recovery rate of 40%, to price the CDS contracts. The discount factors for the bootstrapping algorithm are derived from the yield curve model, which generates rates for the respective time frames. These are then fed back into the bootstrapping algorithm along with a calibrated GDP response factor to price the CDS contracts.

Bootstrapping relies on the principle of no-arbitrage, meaning it assumes there are no opportunities to make risk-free profits by exploiting pricing discrepancies in the market.

INPUTS

REFERENCE DATE SPREADS DATA

MATURITY	SPREAD
6M	16.55
.	.
.	.
.	.
20Y	109.87

HULL WHITE MODE OUTPUT

Market Risk Factor	ISDA _Transition Risk			
	1mo	...	...	12mo
GBP GOV 1D	30	60	80	80
GBP GOV 6M	20	50	70	70
GBP GOV 1Y	10	40	50	60
GBP GOV 5Y	10	30	40	50
GBP GOV 10Y	5	20	30	40
GBP GOV 20Y	5	10	20	30

MACRO-MODEL GDP OUTPUT

HORIZON	GDP
1mo	-0.006
3mo	-0.008
6mo	-0.01
9mo	-0.013
12mo	-0.014

BOOTSTRAP METHOD

CDS Shock = f(Previous CDS Spreads, Hull White Rates, Macro Model GDP Output)

*Based on Phase 2 Data

OUTPUTS

	1d	10d	3mo
Air Transport	20	20	70
Electricity	20	30	80
Mining	25	50	100
Chem Prods	25	30	80
Transport	20	20	80

The model calculates shocked CDS spreads, incorporating GDP forecast and a shocked yield curve derived from the Hull-White model. The bootstrap method progressively calculates CDS spreads for increasing maturities. It uses previously determined spreads and shocked yield curve to determine the spread for the next maturity point.

A.4 Equities Model

The Gordon Growth Model (GGM) is a quantitative method used for deriving the intrinsic value of a company's equity, based on the present value of its future dividend payments. The model operates on the premise that a share's current price reflects the sum of all its future dividend payments, discounted back to their present value using a pre-determined discount rate. Using the GGM, future dividends can be discounted and a measure of the present worth of a company's future cash distributions to its equity holders can be calculated.

The same approach was used to model changes in the value of an equity index as a function of changes to prospects for future discounted dividend growth in a particular region or sector. GDP growth and interest rates from the macroeconomic model were used as a proxy for expected future dividend growth and discount rates, respectively.

The GGM assumes that dividends will grow indefinitely at a consistent rate. This is a simplification, as companies rarely exhibit perfectly consistent dividend growth over extended periods. The model places significant emphasis on dividends as the primary driver of value. The GGM is sensitive to the chosen growth rate and required rate of return.

INPUTS

REFERENCE DATA INDEX DATA (FTSE 100)

EXCHANGE DATA	CLOSE
31-Dec-2024	12,729.5234
.	.
.	.
31-Dec-2004	1,799.5477

MACRO-MODEL RATES/GDP OUTPUTS

HORIZON	GDP	IR
1mo	-0.006	0.002
3mo	-0.008	0.003
6mo	-0.01	0.005
9mo	-0.013	0.005
12mo	-0.014	0.006

GORDON GROWTH MODEL

$P = \frac{D_1}{r - g}$: P: Change in price, r: Rate, g: GDP

*Based on Phase 2 Data

OUTPUTS

		1d	10d	3mo
UK	FTSE 100	-5%	-10%	-10%
US	S&P 500	-5%	-10%	-15%
Asia	NIKKEI225	-5%	-10%	-15%
China	SSC 100	.	.	.
SA	FTSE/JSE Top 40	.	.	.
Canada	S&P/TSX 60	.	.	.
Ausrtalia	S&P/ASX200	.	.	.

Equity price shocks are driven by interest rate and GDP shocks (as a proxy for profits/ dividend growth), impacting profits and dividend growth. These effects are then modelled at a sector level, using regression to link ABM-derived Phase II sector equity outputs with new geographic data.

A.5 FX Model

To quantify the FX impact, an uncovered interest rate parity (UIP) model was used, linking differences in interest rates between two currencies. The relative change in rate should be reflected in the future change of the exchange rate between those currencies. The model assumption is that investors should earn the same return from holding either currency, despite differing interest rates. For example, if Japanese interest rates are higher than US rates, the UIP suggests the Japanese yen should depreciate against the US dollar. This depreciation would offset the higher interest earned on Japanese assets, equalizing returns for investors holding either currency. Therefore, forecasted interest rates from the ABM were used to calculate an exchange rate per timestep.

Uncovered interest parity also includes a risk premium term to account for deviations between expected changes and interest rate differentials and can reflect factors such as historical economic or political instability. Such a term has been included in the model, with the applied risk premium calculated based on average deviation between change implied by interest rate differentials and observed change in the exchange rate across time series for each currency pair.

One limitation of the model is that the expected future exchange rate is unobservable, so actual and expected changes in exchange rates have been assumed to be equal over the scenario horizon, such that interest rate differentials drive changes in exchanges rates. The impact of other factors has been recognized through the use of the risk premia term.

INPUTS

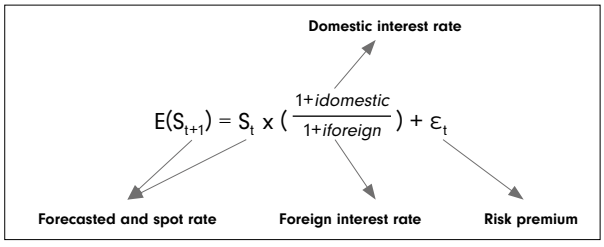
REFERENCE DATE

DATE	USDCNY	USDZAR	USDCAD	USDAUD
01/12/2014	6.878	11.106	1.153	1.153
01/05/2018	6.333	11.855	1.287	1.153
...	...	...	...	...
...	...	...	...	...
03/06/2024	7.242	18.698	1.367	1.371

MACRO-MODEL RATES OUTPUT

HORIZON	IR
1mo	0.002
3mo	0.003
6mo	0.005
9mo	0.005
12mo	0.006

GORDON GROWTH MODEL



*Based on Phase 2 Data

OUTPUTS

Market Risk Factor	ISDA Transition Risk		
	1d	10d	3mo
USDINR	-5%	-10%	-15%
USDJPY	0%	0%	0%
USDEUR	0%	0%	0%
USDBRL	-5%	-10%	-15%
USDCNY	...	...	...
USDZAR	...	...	...
USDCAD	...	...	...
USDAUD	...	...	...

The shock is quantified as the spot exchange rate multiplied by the % difference between the baseline interest rate at the reference data and the shocks interest rates of the domestic and foreign rates, which incorporate the rate delta derived from the Macro Model output. Time-varying risk premium average is added to account for the volatilities of historical observations.

A.6 Commodities Model

A regression-based approach was used to predict commodity prices based on historical relationships with economic output. Commodity price predictability has been shown to be closely linked to the economic cycle, with this relationship being strongest in periods of economic recession. Here, a random forest regression model is trained on the relationship between the GDP of the economies in the macroeconomic model and historical commodity prices.

Commodity prices are taken at quarterly intervals to match the frequency of the macroeconomic data between 2000 and 2020, inclusive. When regressing commodity prices on macroeconomic variables, out-of-sample predictability has been shown to be greatest for a quarterly horizon. For the short-term horizons considered in this paper, historical correlations were assumed to hold as traders and consumers use existing schemas and/or models to drive behavior. The trained regressor was then used to predict commodity prices using the forecasts from the macro model.

This approach assumes a stable relationship exists between the chosen explanatory variables and commodity prices. Additionally, relying solely on historical data for model training assumes past relationships will persist, potentially overlooking structural changes in the market or changing trends.

ECONOMIC INPUTS

	HISTORIC GDP DATA			HISTORIC COMMODITIES PRICES		
DATE	GDP UK	...	GDP JP	GOLD	...	CRUDE
1/1/2001	-0.009	...	-0.11	278	...	51.5
.	...	...	...	...	...	...
.	...	...	...	...	...	...
30/12/2023	0.08	...	-0.01	2322	...	77.5

MODEL CONSTRUCTION

Here, a Random Forest model is trained on the relationship between the historic GDP of the economies modelled by the macroeconomic ABM and historic commodity prices. Commodity prices are then forecast by the ABM GDP output.

ABM ECONOMIC FORECASTS

Macropeconomic Variable	MACRO MODEL GDP FORECAST		
	1mo	...	12mo
GDP UK	-0.6%	...	-1.4%
...	...	...	...
GDP JP	-1.1%	...	-2.6%

*Based on Phase 2 Data

OUTPUTS

	LIQUIDITY HORIZON			
Asset class	1d	...	...	1y
GOLD	5%	...	...	20%
...	...	...	...	...
WTI CRUDE	-5%	...	...	-30%

ABOUT ISDA

Since 1985, ISDA has worked to make the global derivatives markets safer and more efficient. Today, ISDA has over 1,000 member institutions from 76 countries. These members comprise a broad range of derivatives market participants, including corporations, investment managers, government and supranational entities, insurance companies, energy and commodities firms, and international and regional banks. In addition to market participants, members also include key components of the derivatives market infrastructure, such as exchanges, intermediaries, clearing houses and repositories, as well as law firms, accounting firms and other service providers. Information about ISDA and its activities is available on the Association's website: www.isda.org. Follow us on LinkedIn and YouTube.