Pilot Scenario Analysis Exercise on Climate-Related Risks Based on Common Scenarios

August 2022

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Executive Summary

- The Financial Services Agency (FSA) and the Bank of Japan (BOJ), in cooperation with three major banks and three major non-life insurance groups, conducted a pilot scenario analysis using scenarios published by the Network for Greening the Financial System (NGFS)[1] as common scenarios, in response to the recommendations by the Expert Panel on Sustainable Finance. This attempt is in line with the recent efforts of many central banks and supervisory authorities to understand the impacts of climate change on the financial system and financial institutions through scenario analyses on climate-related risks with common scenarios across financial institutions.

- With data availability limited and no standard analytical method established for climate-related scenario analysis, this exercise was not intended to assess quantitative impacts of climate change on the financial system and financial institutions. Rather, the FSA and BOJ considered this exercise as a means to continuously improve the scenario analysis and focused on understanding data constraints, assessing the validity of analytical assumptions and methods, and identifying issues for future improvement.

- The FSA and BOJ adopted a bottom-up approach, whereby the FSA and BOJ laid out a basic framework with three NGFS scenarios (namely, Net Zero 2050, Delayed transition, and Current policies) and let financial institutions conduct the analysis with their own models in line with the framework.[2]

- Regarding banks' analysis, the FSA and BOJ examined the impacts of both transition and physical risks (mainly acute risks by floods) to assess the mid- to long-term effects of climate change on banks' business and financial soundness via credit risks, based on credit exposures as of March 31, 2021.

- The results indicated that the banks' estimated increase in annual credit costs due to transition and physical risks was considerably lower than their average annual net income. The levels of the estimated increase in credit costs were not significantly different from those published by individual banks in their TCFD Reports, although caution is warranted in the comparison due to the differences in models and sectors

[1] In December 2017, the NGFS was established by central banks and financial supervisors willing to discuss financial supervisory practices to address climate-related risks.

[2] Risks to businesses caused by climate change are generally classified into transition risks related to changes in regulations, technologies, and market environments in the transition to carbon neutrality, and physical risks related to changes in climate and weather. Physical risks can be further classified into risks arising from an increase in the frequency and intensity of natural disasters, such as typhoons and floods (acute risks), and risks that gradually manifest in response to long-term changes in precipitation, temperature, sea levels, etc. (chronic risks).

covered. The results also demonstrated that each bank had the capacity to conduct a risk analysis not only for the scenarios set in its own TCFD Report but also for the common scenarios of the exercise (NGFS scenarios). However, note that the results should not be interpreted as a definitive assessment of the impacts of climate-related risks, as the objective of the exercise is not to provide a quantitative assessment of climate-related risks.

- On the other hand, the exercise also revealed that the estimated results significantly depend not only on banks' analytical models and the selection of variables for the models, but also on additional assumptions made by each bank. With a lack of information and data on future prospects, the assumptions varied in how businesses and technologies in the specific sectors will evolve, whether and how clients' business models will be transformed, to what extent clients will be required to finance in transforming their business, and to what extent increased carbon prices will be passed on to the selling prices.

- To understand the issues in risk estimation and enhancing risk management at individual banks through horizontal reviews, it is important to ensure more comparability across banks in the exercise, including through encouraging the use of common assumptions. On the other hand, the application of a scenario analysis in engagement with clients to support addressing climate change would require banks to refine their analysis of individual companies. In the course of refinement, banks may need to consider the impacts of structural changes in related industries on individual companies as well as the effects of business transformation by individual companies with banks' engagement.

- Regarding non-life insurers' analysis, the FSA focused on physical risks (acute risks by typhoons and floods) related to their underwriting business and assessed the magnitude of climate-driven physical risks (as changes in insurance claim payments) by using the scenarios with an intensified magnitude of specific disasters. The results showed that claim payments increase as temperatures rise. However, it was also shown that analyzing specific scenarios (disasters) is insufficient to assess changes in the probability/frequency of the occurrence of disasters in the future and that the results vary due to limitation in uniformity of assumptions and risk models of each non-life insurance group. In order to overcome these issues, the FSA would need to consider conducting a stochastic analysis that takes into account the probability of occurrence of various scenarios which incorporate the impact of future climate change, using the same risk model across the non-life insurance companies.

- To utilize the scenario analysis in the business strategy development and risk management, financial institutions need to further enhance the methodology, including addressing the issues identified in the exercise, taking into account their risk profiles as well as international discussions and developments in practice. Going forward, the FSA and BOJ will continue dialogue with financial institutions on methods and practical application of the scenario analysis, including on how to address the issues identified in the exercise. The FSA and BOJ will also contribute to the improvement of standard scenarios and international data initiatives, including through sharing the issues identified in this exercise with central banks and supervisory authorities at international forums.

I. Background and purpose

Climate-related risks are likely to materialize over the medium to long-term, and how they materialize and the significance of their impacts when materialized are highly uncertain. Scenario analysis is considered to be an effective tool to quantitatively assess climate-related risks. It uses simulations to assess the timing and magnitude of impacts on financial institutions' earnings and financial soundness via plausible transmission mechanisms under certain scenarios about future rise in temperatures and policy responses by governments. The Task Force on Climate-related Financial Disclosures (TCFD) encourages financial institutions to undertake scenario analysis for the risk assessment.[3]

Many central banks and supervisory authorities around the world, in cooperation with financial institutions, have conducted scenario analyses on climate-related risks. In Japan, the report of the Expert Panel on Sustainable Finance (Building a Financial System that Supports a Sustainable Society)[4,5] released in June 2021 recommended undertaking a pilot exercise of scenario analysis, in particular for large financial institutions.

Based on this recommendation, the FSA and BOJ, in collaboration with three major banks and three major non-life insurance groups, conducted a pilot scenario analysis based on common scenarios.[6,7]

At present, however, the development in analytical methods and data collection for the scenario analysis is still in progress, and thus there are some variations in scenarios and risk estimation methods used in domestic and overseas scenario analyses. Therefore, the FSA and BOJ considered this exercise as a means to continuously improve the scenario analysis and focused on understanding data constraints, assessing the validity

[3] June 2017, final report "Recommendations from the Task Force on Climate-related Financial Disclosures" (TCFD Recommendations).
[4] July 2022, the Expert Panel on Sustainable Finance published its Second Report "Financial Systems That Open up a New Sustainable Society."
[5] In response to the recommendations prescribed in the report, the FSA published "Supervisory Guidance on Climate-related Risk Management and Client Engagement." This guidance documents viewpoints of supervisory dialogues regarding financial institutions' climate-related risk management, including the use of scenario analyses.
[6] Mizuho Financial Group, Sumitomo Mitsui Financial Group, and Mitsubishi UFJ Financial Group (as of the end of March 2021): The three mega-banks' share of the total loan balance of domestic banks is approximately 50%.
[7] MS&AD Insurance Group Holdings, Sompo Holdings, and Tokio Marine Holdings. As of the end of March 2021, the three major groups accounted for around 90% of all domestic non-life fire insurance business (direct premiums written).

of analytical assumptions and methods, and identifying issues for future improvement.

II. Scenario design

While the number of financial institutions participating in the scenario analysis and analytical approaches vary among jurisdictions, the procedure of the scenario analysis can be broadly divided into scenario design and estimation of financial risks under each scenario. For scenario design, many supervisory authorities and central banks have adopted the scenarios published by the Network for Greening the Financial System (NGFS) as their basis (Boxes 1 and 2). Moreover, the Basel Committee on Banking Supervision published "Principles for the Effective Management and Supervision of Climate-related Financial Risks" in June 2022, which also recommends the use of "common scenarios where appropriate" in order to promote international cooperation, given that climate change and its mitigations are global issues. Given these developments, the NGFS climate scenarios were adopted as the common scenarios in this pilot exercise.

The FSA and BOJ adopted the second version of the NGFS climate scenarios published in 2021 (the first version was published in 2020). The NGFS climate scenarios are comprised of total six scenarios (Figures 1 and 2)—i.e. two scenarios in each three categories (orderly transition, disorderly transition, and hot house world). Each scenario includes pathways of variables (e.g. carbon prices) from 2020 to 2100 (with some variables up to 2050) consistent with scenario narratives that represent structural climate-related changes in society and economy (Figures 3 and 4).

In the exercise, three scenarios were adopted: Net Zero 2050, Delayed transition, and Current policies. Net Zero 2050 scenario assumes that steady global efforts will start as early as 2020s and carbon neutrality will be achieved by 2050 and exposes financial institutions with relatively higher transitions risks, while posing the smallest physical risk due to the smallest temperature rise. In contrast, the Current policies scenario assumes that no additional measure will be taken to combat global warming, so financial institutions would face largest physical risk—and the smallest transition risk—among the three scenarios due to the accelerated global warming. Furthermore, the Delayed transition scenario assumes that no efforts will be undertaken to transition to a decarbonized society in the 2020s, but the governments will make a policy turnaround in 2030 and carbon neutrality will be achieved around 2050. The impacts of such rapid transition due to the delay in policy responses will materialize as transition risk.

The variables in each scenario and a technical explanation for scenario development

are available on the NGFS's portal site. In April 2022, the FSA published the report "Study on Climate-related Scenario Analysis," which provides an overview and features of NGFS scenarios.

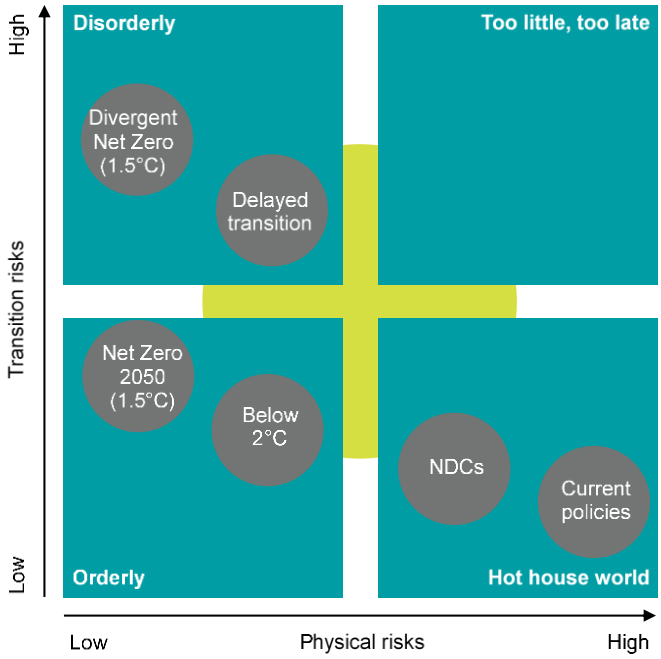
Figure 1: Narrative of NGFS scenarios (2nd edition)

Category	Scenarios	Narrative
Orderly	Net Zero 2050	Reduce global warming to 1.5°C through strict emission reduction policies and innovation, aiming to reduce global CO2 emissions to net 0 by around 2050. Some countries, such as the United States, EU and Japan, achieve net 0 emissions for all greenhouse gases.
	Below 2°C	Emission reduction policies are becoming increasingly stringent, and there is a 67% chance that global warming will be kept below 2°C.
Disorderly	Divergent Net Zero	Reach net zero by around 2050; heterogeneous policies implemented across sectors lead to higher costs and faster phase-out of oil use.
	Delayed transition	Annual emissions will not decline until 2030; strong policies are needed to limit warming to 2°C; limited CO2 removal.
Hot house world	Nationally Determined Contributions (NDCs)[8]	It is assumed that all policies that each country has committed to (including those that are not currently implemented) will be implemented.
	Current policies	Only policies currently in place are assumed to be retained. Physical risks are higher.

Source: Excerpt from FSA's "Study on Climate-related Scenario Analysis"

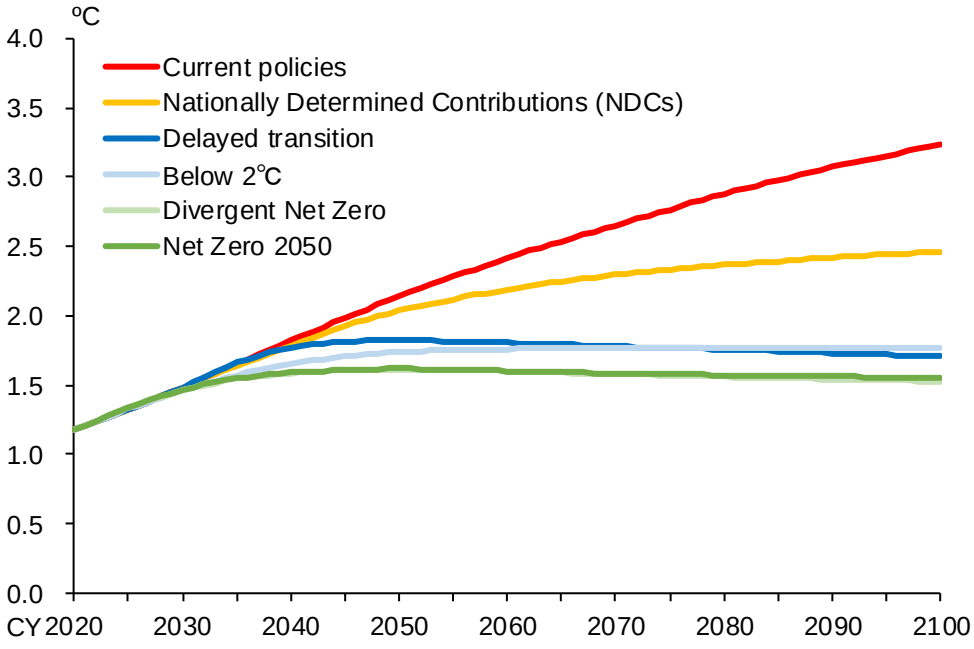
[8] NDCs (Nationally Determined Contributions) are emissions reduction targets set by each country under the Paris Agreement. Although countries are required to submit NDCs every five years, the second edition of the NGFS reflects national energy and emissions targets for 2025 and 2030 that were submitted as of December 2020 (assuming that similar climate policies will be maintained after 2030), but does not reflect targets submitted after 2021 (e.g., Japan's target to reduce emissions by 46% by 2030 compared to 2013 and the United States' target to reduce emissions by 50-52% by 2030 compared to 2005).

Figure 2: Scenario positioning of NGFS scenarios (2nd edition)



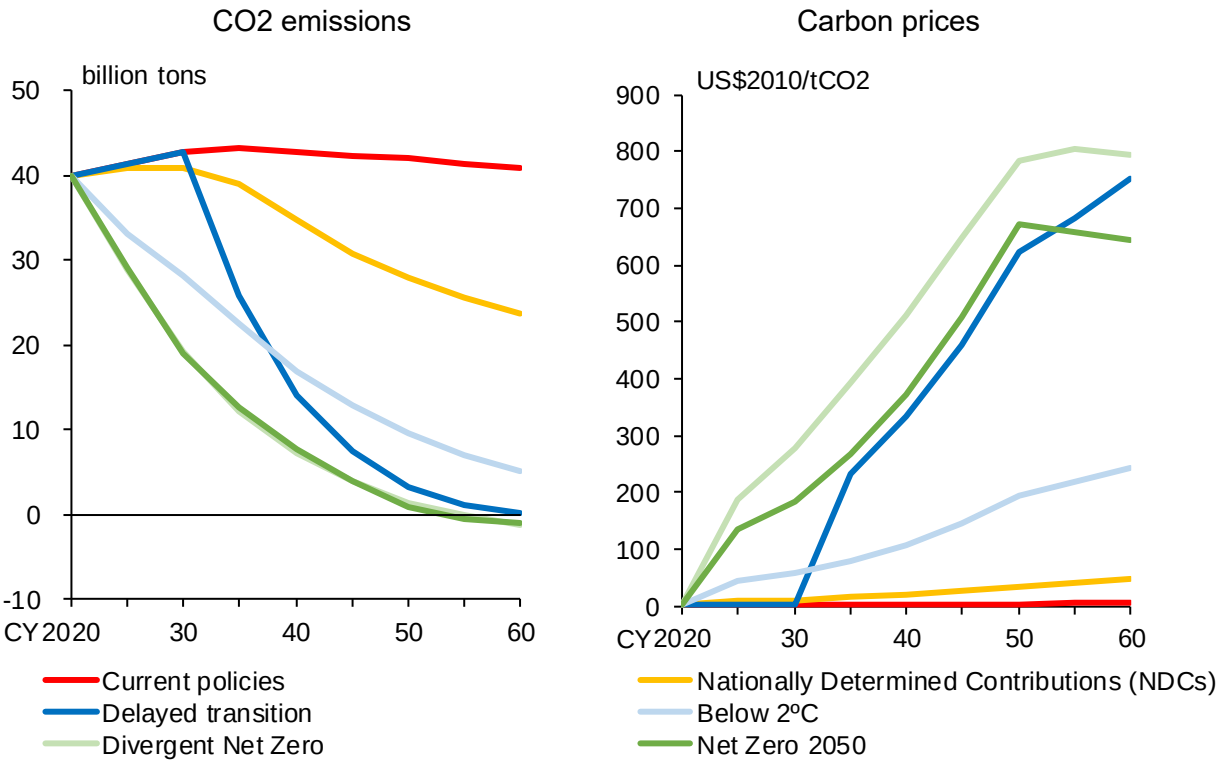
Source: NGFS scenarios (2nd edition) (prepared by the FSA and BOJ)

Figure 3: Global mean temperature increase under NGFS scenarios (2nd edition) (relative to 1850 -1900 average)



Source: NGFS scenarios (2nd edition) (prepared by the FSA and BOJ)

Figure 4: CO2 emissions and carbon price assumptions in NGFS scenarios (2nd edition)



Source: NGFS scenarios (2nd edition) (prepared by the FSA and BOJ)

BOX 1 Efforts to develop a framework for climate-related risk analysis by NGFS

The Paris Agreement, adopted in 2015, stipulates that the increase in global average temperature increases should be held to well below 2°C above pre-industrial levels, and efforts should be pursed to limit them to 1.5°C. In response, many countries are moving forward with initiatives to address climate change, with the goal of achieving carbon neutrality by 2050. Under such circumstances, it has been pointed out that losses arising from the obsolescence of assets currently subject to investment and financing may pose a risk that threatens financial stability (Carney, 2015 ; Bolton et al., 2020).

However, climate-related risks, both physical and transition risks, can materialize in ways that are significantly different from those previously observed. Therefore, it is possible that a quantitative analysis based only on data on losses observed in the past may not be sufficient to capture risks. Under such circumstances, a consensus is emerging that forward-looking methods, such as scenario analysis, which estimates losses taking into account the future outlook for climate change and climate change measures, are suitable for quantitative measurement of climate-related risks (UNEP FI, 2018; 2019).

In carrying out scenario analysis, it is necessary to design scenarios that take into account the interdependence between climate change and economic activities. Following William Nordhaus's proposal of the DICE model in the 1990s, a large variety of Integrated Assessment Models (IAMs) that takes into account the interdependence between climate change and economic activities have been proposed. However, it has been pointed out that a large portion of the transmission mechanisms of climate related risks remain unknown and that there are many challenges in applying IAMs to policy decision making (Pindyck, 2021; Barnett et al., 2022).

As described above, scenario analysis to quantitatively assess climate-related risks requires a wide range of knowledge to design scenarios as the first step. Many financial supervisory authorities and central banks thought it would be beyond their capacity to deal with these issues independently due to resource constraints.

Under these circumstances, the NGFS published scenarios for the analysis of climate-related risks (the NGFS scenarios) in 2020, followed by the publication of its second edition in 2021, in collaboration with research institutions developing large-scale IAMs, such as the Joint Global Change Research Institute (JGCRI; developing and operating the GCAM), the International Institute for Applied Systems Analysis (IIASA; developing and operating the MESSAGE), and the Potsdam Institute for Climate Impact Research (PIK; developing and operating the REMIND).

The NGFS scenarios provide projections over 30 to 80 years for hundreds of variables per region, including greenhouse gas emissions, climate change-related variables such as temperature increases, energy-related variables such as fossil fuel consumption and renewable energy production, and financial and economic variables such as GDP and inflation rates, by combining the IAMs with a macro-econometric model (NiGEM). Since the provision of sector-specific information for NGFS scenarios is limited, except for sectors related to fossil fuels, overseas financial supervisory authorities and central banks sometimes use data derived from their Computable General Equilibrium Model as a complement.

BOX 2 International efforts to analyze the impact of climate-related risks on financial stability

According to a survey of member financial supervisory authorities and central banks published by the NGFS in October 2021, approximately 30 financial supervisory authorities and central banks were engaged in scenario analysis. According to the survey results, the situation in each country is as follows, and the framework of Japan's pilot exercise is generally consistent with that adopted by many jurisdictions.

1. As for the objectives of scenario analysis, most jurisdictions point out the following: (1) understanding the impact on individual financial institutions or the financial system as a whole; (2) improving the analytical capabilities of both financial supervisory authorities and financial institutions; and (3) identifying data gaps for conducting the scenario analysis. At present, however, no jurisdiction is considering regulatory and supervisory measures such as additional capital charges based on the results of the scenario analysis. For this reason, many jurisdictions consider scenario analysis as a "pilot exercise," as did Japan.

2. The approaches to the scenario analysis are divided into the top-down approach, in which the financial supervisory authorities and central banks are in charge of both scenario design and risk analysis, and the bottom-up approach, in which the financial supervisory authorities and central banks are in charge of scenario design, and financial institutions are in charge of risk analysis.

3. In addition to banks' credit risk, some jurisdictions also analyze banks' market

risk and insurers, investment funds, and pension funds.

4. The risks covered by the scenario analysis are only transition risk or both transition risk and physical risk, with the exception of one jurisdiction, which covers only physical risk.

5. The time horizon for the scenario analysis is about 30 years, as many countries have set greenhouse gas reduction targets by 2050 under the Paris Agreement. However, there are some jurisdictions that set 50 to 80 years for analysis in order to see the longer-term impact of physical risks.

As for development in the asset composition of financial institutions participating in the scenario analysis, approximately three quarters of jurisdictions adopt static balance sheets that do not assume changes during the analysis period. However, some authorities, including those in emerging economies, adopt dynamic balance sheets that assume changes in asset composition.

III. Financial risk analysis at banks

1. Analytical Framework

(1) General

As the Task Force on Climate-related Financial Risks (TFCR) of the Basel Committee on Banking Supervision summarized in its 2021 report, climate-related risks (transition and physical risks) are drivers of existing financial risks (market risks, credit risks, etc.) and do not add a new risk category to existing financial risks (Figure 5). Therefore, scenario analysis of climate-related risks can be described as estimation of existing financial risks driven by transition and physical risks under selected scenarios.

The pilot scenario analysis for banks measured the impacts of both transition and physical risks only on credit risk, considering the mid- to long-term impacts of climate-related risks on banks' sound management and financials.

The analysis is based on a static balance sheet where the borrowers and amounts of loans are fixed as of the end of March 2021, focusing on assessing the risks in banks' balance sheets at this time, given the difficulties in reasonably predicting banks' behavior over a long period of time.

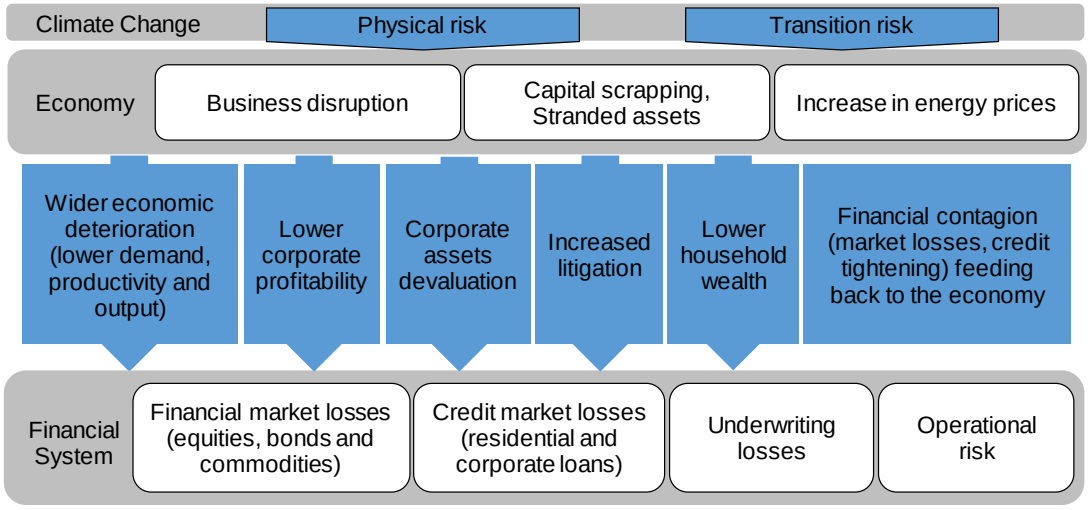
The banks were expected to primarily use variables published by the NGFS in their analysis. However, while the NGFS scenarios provide macroeconomic variables, the availability of the sectoral breakdown is limited, except for some sectors with high greenhouse gas emissions. Thus, the BOJ decided to provide supplementary data, such as GDP, by sector that are not included in the NGFS scenarios for the common use by the banks to ensure comparability (BOX 3), and allow the banks to use external data on other variables necessary for their own models.

The scenario analysis can be broadly classified into two groups depending on the role of supervisors and banks. The first is a top-down approach, where supervisory authorities and central banks design scenarios and analyze climate-related financial risks. The second is a bottom-up approach, where supervisory authorities and central banks design scenarios and request financial institutions to analyze climate-related financial risks based on the scenarios. The FSA and BOJ adopted the bottom-up approach because the pilot exercise focused on identifying analytical challenges and accumulating their analytical capacity, rather than quantitatively evaluating the impact of climate-related risks on the

financial system.

Given that standard analytical methods and data collection for estimating credit risk are still internationally at the development stage, the FSA and BOJ set up the basic framework described below to enhance comparability in the bottom-up analysis and requested each bank to undertake analysis under the framework, customizing their models used for their scenario analysis in the TCFD Report. Then, the FSA and BOJ engaged in dialogues with the banks regarding their adopted model design to measure risks under the three scenarios in the exercise.

Figure 5: Overview of transmission channels for climate-related financial risks to banks' financial strength



Source: Excerpt from NGFS, "A Call for action: Climate change as a source of financial risk," prepared by the FSA and BOJ

(2) Transition risk

For transition risk, three scenarios were used: Net Zero 2050, Delayed transition, and Current policies. Under each scenario, changes in credit costs for domestic and overseas exposures were estimated at five year intervals up to 2050.

Among all domestic and overseas credit exposures covered in the estimation, the banks were allowed to take two different approaches by sector, taking into account the magnitude of transition risk of each sector and the size of its exposure in each bank's credit portfolio.

Specifically, for those sectors that were identified by banks based on CO2 emissions and credit exposures to bear significant climate-related risks (key sectors), the FSA and BOJ requested each bank to develop an analytical framework capable of capturing sector-specific risk factors and to estimate additional credit costs for the entire sector based on the estimate from a group of sampled individual firms to reflect differences in business models among firms in the sector.[9]

On the other hand, for the other sectors (including households), the banks were allowed to conduct analyses using macroeconomic indicators, etc. (for example, through customizing their stress testing models for this exercise), instead of developing models similar to those for the key sectors that reflect the characteristics of individual sectors and firms.

(3) Physical risk

Physical risk can be classified into risks caused by severe natural disasters (acute physical risk) and those gradually caused by long-term changes in climate patterns arising from, for example, temperature and sea level rise (chronic physical risk). In this exercise, the FSA and BOJ designed the framework of the exercise to cover only acute physical risk by taking into account the magnitude of impacts on banks and the accumulated banks' modelling capacity. In particular, the FSA and BOJ focused on risks such as damage to assets and collateral and suspension of business activities due to floods and typhoons.[10]

Two scenarios, Net Zero 2050 and Current policies, were used to estimate the cumulative credit costs on domestic exposure through 2050 and through 2100, respectively. As pointed out in the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), the impact of a lack of action to reduce greenhouse gas emissions is likely to become apparent in the second half of this century, thus the analysis of physical risk covered a longer period than transition risk. In the NGFS scenarios, consistent with these scientific assessments, the temperature increase under the Current policies scenario, which assumes measures will not be taken to combat global warming, is expected to be around 2.1°C as of 2050, only slightly higher than the

[9] We also left the number of sample firms to each bank's discretion, but we expected that multiple samples would be drawn from each segment based on industries and geographic areas in order to give an overall picture of the sector.

[10] Since chronic physical risks are likely to be reflected in the NGFS scenarios as a reduction in GDP due to temperature increases, this exercise estimates the impact of acute physical risks.

temperature increase (1.5°C) under the Net Zero 2050 scenario. Therefore, the difference in credit losses over the period through 2050 between the Current policies scenario and the Net Zero 2050 scenario might not well capture the difference in physical risk between the two scenarios.

The NGFS scenarios provide information related to physical risks, such as the frequency and scale of natural disasters by region based on temperature increases. However, they do not include detailed hazard map information that are already used by Japanese banks to assess flood and typhoon risks—e.g., information on land elevation, topography, and river basin. Therefore, the banks were allowed to apply the estimation methods with hazard maps, instead of the NGFS scenario data, that the banks had used in their past analyses with scenarios of the past IPCC ARs, while ensuring their consistency with temperature levels in the NGFS scenarios.

Figure 6: Overview of scenario analysis by banks

	Transition risk	Physical risk (acute risk)
Balance sheet	Borrowers and amounts are fixed as of the end of March 2021 (assuming a static balance sheet).	
Scenarios	Net Zero 2050 Delayed transition Current policies	Net Zero 2050 Current policies
Impacts to be considered	Impacts of policies and regulations, technological innovations, market changes, etc., arising as responses to climate change to climate change.	Damage to assets and collateral due to floods, suspension of business activities (Wind damage if possible)
Analysis period and scope	2021-2050 (every five years) Domestic and overseas credit (Credit risk)	- 2050, - 2100 Domestic Credit (Credit risk)
Analytical approach	① Sectors with significant impacts of climate-related risks ➢ Conducted analysis using individual companies or sample companies of each industry type ② Other sectors ➢ Analysis using macroeconomic indicators is also possible.	Not specified

BOX 3 Developing data elements to complement the NGFS scenarios

The NGFS offers a wide range of variables depending on the scenarios, but the availability of sector-level variables is limited at the time of the second edition, so the BOJ estimated GDP and share prices by sector according to the scenarios based on certain assumptions and provided them to the participating banks. This box explains the methodology.

Greenhouse gas emissions vary widely across sectors, and in a carbon neutral transition scenario, high carbon prices could have a significant impact on high-emission sectors. The impact of these carbon prices on sectoral GDP is estimated by a general equilibrium model that takes into account industrial linkages, which includes 32 industries, each producing goods with intermediate inputs of goods produced by other industries. This model captures spillovers through industrial linkages. For example, if a carbon tax is imposed on the use of fossil fuels, which are major sources of carbon emissions, the fossil fuel sector faces a significant reduction in demand and the added value of the sector is significantly reduced because each sector has a mechanism to substitute intermediate inputs with other goods. Sectors that are highly dependent on fossil fuels face a significant increase in production costs, with higher selling prices and lower output quantity.[11]

The parameters of this model are determined using the 2015 Input-Output Tables and the model estimates a sectoral GDP path that is consistent with the carbon price-GDP path provided by the NGFS scenarios. According to the model, for the oil and coal sectors that face a reduction in demand, the sectoral GDP will decline significantly, while the ceramic, clay and other sectors that emit a large amount of greenhouse gases in their production will also face a relatively large GDP decline.

While the outlook for sectoral GDP may depend on a range of factors, including technological innovations and changes in consumer preferences, this estimate limits itself to the effects of higher carbon prices, and it should be noted that the outcome of the estimate depends on assumptions about the production and utility functions in the model.

The BOJ also provided stock price indexes by sector calculated by a vector

[11] For more information about this estimate, see Matsumura, K., T. Naka, and N. Sudo, "Analysis on the Transmission of Carbon Tax using a Multi-Sector Dynamic and Systemic General Equilibrium Model," Bank of Japan Working Paper Series, forthcoming. This estimate also draws on the analytical approach of the French Central Bank, which uses this framework to assess the impact of transition risks on the financial system, see Devulder and Lisack, 2020.

autoregressive model using sectoral GDP and a stock price index in the NGFS scenarios. As the target of this exercise was credit risk, the use of sectoral indices would have been limited. However, it is also important to improve the framework for creating additional scenarios in preparation for expanding the scope of risk analysis.

2. Common features of banks' estimation methods

The process of scenario analysis differs among banks. This section describes the features of estimation methods for transition and physical risks, which are broadly common to the participating banks.[12]

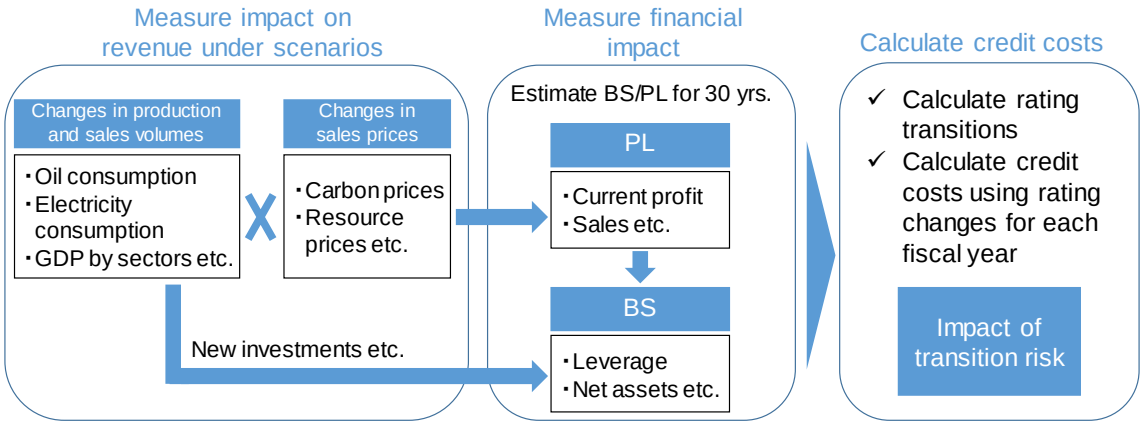
(1) Transition risk

As for the transition risk analysis of key sectors, the banks first measured the impacts on the sampled borrowers' financials based on the disclosure and financial information of each borrower, simulated the credit rating transition, and then applied the results to credit exposure to the whole sector portfolio for the total sector level impact assessment.

For example, the credit ratings of the sampled companies in each year can be estimated by simulating their BS/PL up to 2050 based on projected changes in production, sales volume, and prices as well as the amount of new capital investment required by the scenarios. Then, the rating transition for each sector can be constructed based on the simulated credit rating transitions of sample companies, which would then be used for estimating the impact on credit costs.

[12] As noted above, since the specific analytical approach is based on each bank's ideas, it should be noted that the details of the analytical model vary among banks, and that different models are adopted by sectors within the same bank.

Figure 7: Process for calculating impact from financial simulation of a sample firm



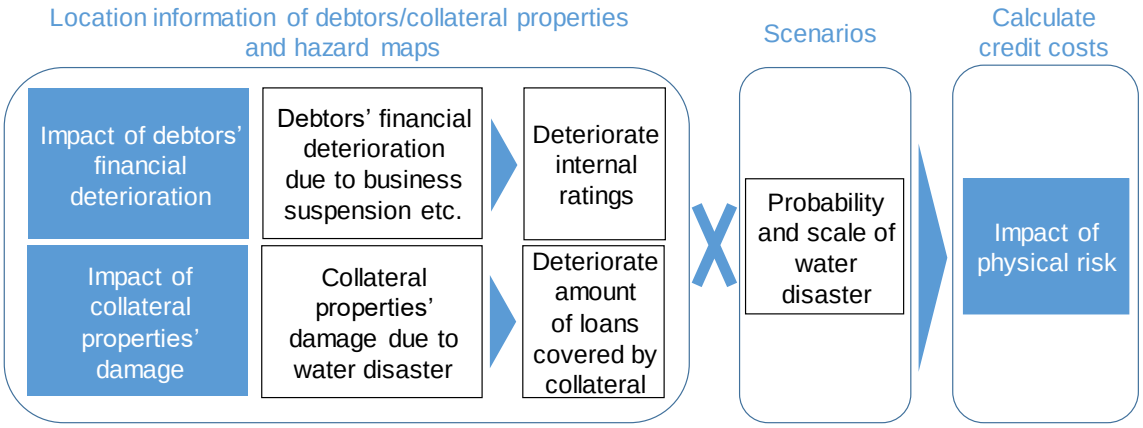
Source: Prepared by the FSA and BOJ with reference to descriptions in each company's TCFD Report

(2) Physical risk

Analytical models for physical risk (mainly floods) mainly used location information of borrowers and collateral properties, hazard maps, and probability of occurrence of disasters.

For example, based on the projections of the extent to which the location of the borrower or collateral property will be flooded in the event of a disaster, one can estimate the financial impacts (conditional on disaster occurring) through financial deterioration and credit rating decline of the borrowers due to business suspension and collateral damages. Then by applying the probability and scale of disaster occurrence for each year based on the temperature outlook for each scenario, the impacts of physical risks up to 2050 and 2100 can be estimated.

Figure 8: Process for calculating flood impact based on debtor information



Source: Prepared by the FSA and BOJ with reference to descriptions in each company's TCFD Report

3. Results and Key Issues

To identify issues related to scenario analysis and accumulate knowledge in both the authorities and financial institutions, the FSA and BOJ analyzed the participating banks' results and engaged in dialogue with the banks.[13]

Since the exercise was not intended to quantitatively evaluate the impact of climate related risks on the financial system, the results described below should not be interpreted as a definitive assessment of the impact of climate-related risks.

The main findings are summarized below.

(1) Transition risk

In this pilot exercise, transition risks were assessed mainly as the differences in estimated credit costs between the Current policies scenario, where transition risk is the smallest, and other 2 scenarios ("estimated transition risk credit costs").

The results indicated that the annual average of estimated transition risk credit costs under both scenarios is considerably lower than the average annual net profits of each bank. Also, the levels of the credit costs estimated by each bank were not significantly different from the results published in banks' TCFD reports, although caution is warranted due to the differences in the models and sectors covered. In addition, banks demonstrated their capacity to conduct their

[13] Several foreign authorities that have published scenario analysis seem to take a similar approach.

risk analysis not only under the scenarios in their own TCFD Report but also under the common scenarios of the exercise (the NGFS scenarios), despite challenges, including those described below.

The results also showed that credit costs from the key sectors accounted for a large part of the estimated transition risk credit costs, with limited contribution from other sectors, in both the Net Zero 2050 scenario and the Delayed transition scenario. One possible explanation is that non-key sectors tend to produce lower carbon emissions than the key sectors and thus may face limited impacts from climate related risks. Another possible explanation is that, while the models for non-key sectors make simple estimates using macroeconomic variables, such as GDPs and the unemployment rates, the projected paths of such variables showed limited divergence over the analyzed period among the three NGFS scenarios, leading to small differences in credit costs between scenarios.[14]

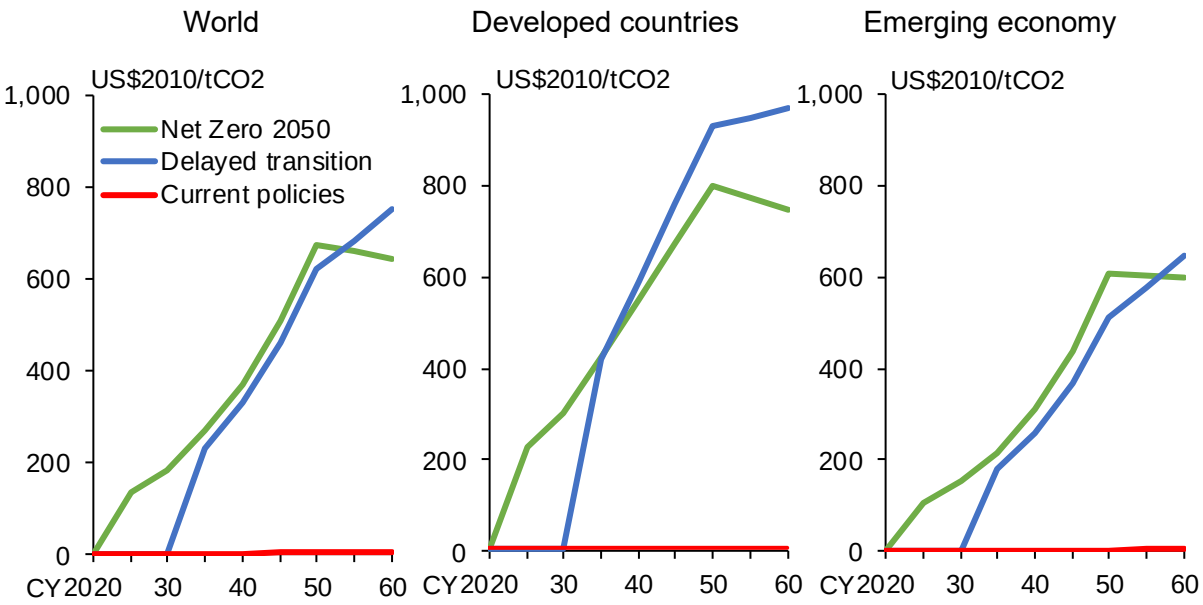
(Comparison between scenarios)

The Delayed transition scenario is a scenario in which policies to reduce greenhouse gas emissions are not introduced until 2030, emissions are rapidly reduced after 2030, and carbon neutrality is achieved by around 2050. Due to such a rapid transition process, transition risk in the Delayed transition scenario was expected to be greater than that in the Net Zero 2050 scenario. However, the results illustrated that the estimated transition risk credit costs in the Net Zero 2050 scenario exceeded those in the Delayed transition scenario.

Carbon price projections in the NGFS scenarios conceivably caused this result. Due to having a significant impact on estimated credit costs through raising production costs, carbon prices are a key indicator of climate-related risks in the banks' models. However, the levels of carbon prices under the Delayed transition scenario are not significantly higher than the Net Zero 2050 scenario when averaged over the analysis period. In fact, carbon prices under the Net Zero 2050 scenario are projected to be somewhat higher than those under the Delayed transition scenario until the 2040s in developed countries and until the 2050s in emerging economies and the world as a whole (Figure 9).

[14] A similar statement was made in the Climate Change Scenario Analysis (covering transition risks only) published in the November 2021 Financial System Report of the Bundesbank of Germany.

Figure 9: Changes in global carbon prices in developed and emerging economies



Source: NGFS scenarios (2nd edition) (prepared by the FSA and BOJ)

In both scenarios, each country is assumed to implement emission reduction measures in line with its declared carbon neutrality target. For example, in the Delayed transition scenario, those countries that declared to achieve carbon neutrality in 2050 will reduce their emissions within 20 years, which is 10 years shorter than in the Net Zero 2050 scenario. Thus, carbon prices in those countries rise at a faster pace and to a higher level in the Delayed transition scenario than in the Net Zero 2050 scenario. On the other hand, for those countries that set their carbon neutrality target after 2050, as do many emerging countries, the initial delay in the transition to a carbon-free society may not have a significant impact on carbon prices.

In order to better understand transition risks associated with delays in addressing climate change, it is important to take into account the abovementioned features of the NGFS scenarios and the banks' models, deepen understanding of the risk transmission channels in each scenario, consider how to reflect them in the model, and review the framework of the exercise as necessary.[15]

[15] Some authorities set additional country-specific common variables based on NGFS scenarios. For example, according to the publication in May 2022, the Bank of England (BOE) provided financial institutions with scenarios and variables that impose additional stress on NGFS's Delayed transition scenario.

(Issues related to analysis of individual sectors)

The breakdown of the estimated transition risk credit costs by sector illustrated that those from the key sectors accounted for a large part of the total credit costs for both the Net Zero 2050 scenario and the Delayed transition scenario.

On the other hand, a sector-by-sector comparison showed some variation in the estimated transition risk credit costs by the banks. The estimated results significantly depend not only on banks' analytical models and the selection of input variables for the models, but also on additional assumptions made by each bank. With insufficient information and data on future prospects, the assumptions varied in how businesses and technologies in the specific sectors will evolve, whether and how clients' business models will be transformed, to what extent clients will be required to finance in transforming their business, and to what extent increased carbon prices will be passed on to the selling prices.

It is important for the banks to form their own outlook on each sector, based on collected information and analysis, for the climate-related risk management. However, for the authorities to better understand the issues in risk estimation and enhancing risk management at each bank through horizontal reviews, it is critical to ensure more comparability across banks in the exercise, including through encouraging the use of common assumptions.

In addition, how changes in production and business in the key sectors could spill over to the other sectors, which were not captured by the banks in their analysis in the exercise, may be one issue for future analysis.

The following section summarizes the characteristics and issues of banks' credit cost estimation models for each key sector, including the variations in additional assumptions made by banks.

① Energy (oil and gas) sector

Prices of fossil fuels (oil, coal, and natural gas) and fossil fuel based products in the energy sector are projected to increase as carbon prices rise by 2050 in both the Net Zero 2050 scenario and the Delayed transition scenario, while extraction and sales of fossil fuels contract significantly as global demand declines mainly in developed countries (Figure 10).

The banks constructed their models and estimated credit costs based on the above outlook for the energy sector. Key parameters in their models include

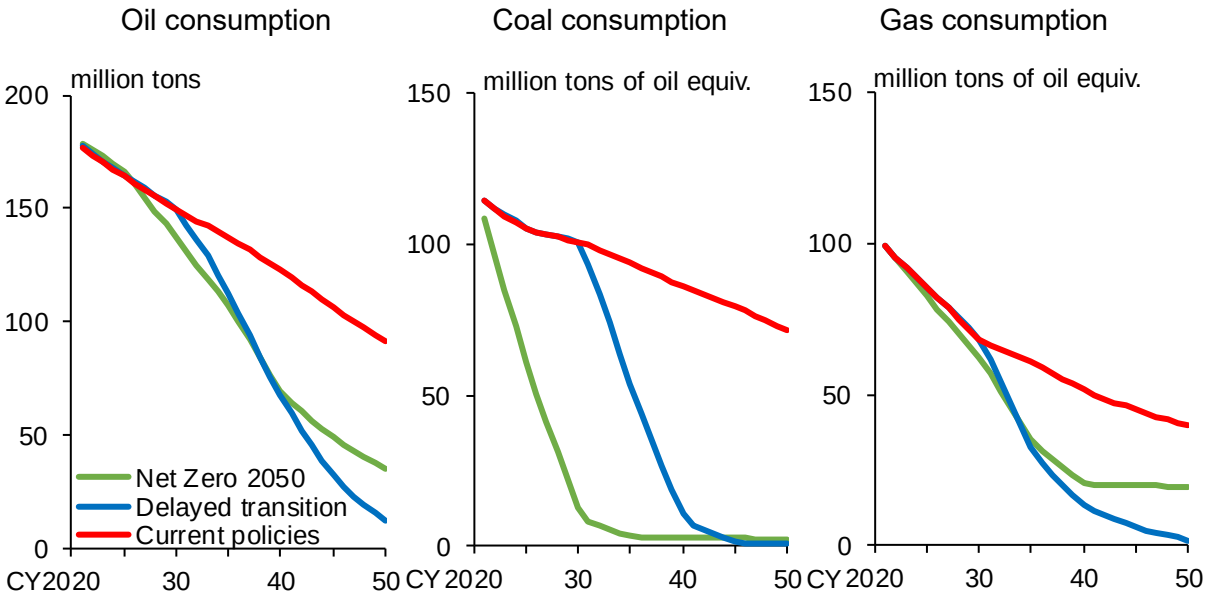
fossil fuel prices, fossil fuel consumption, and carbon price burdens from fossil fuel use.

The results showed that all participating banks saw higher estimated transition risk credit costs for the energy sector than those for the other sectors. This is likely because the negative impacts to existing fossil fuel businesses—due to lower fossil fuel demand and higher carbon price burden—largely outweighed the positive impacts from rising prices of fossil fuels (oil, coal, and natural gas) and fossil fuel based products.

On the other hand, the estimated results varied among participating banks, reflecting differences in their model characteristics and the key assumptions: the prospects of fossil fuel related businesses; the share of business converted to renewable energy businesses; and the pass-through rate of carbon price burdens on product prices.

Complemental analysis of one participating bank, which assumed no business conversion in the above estimates, showed that conversion to renewable energy business and progress in carbon reduction and capture could partially offset the profit decline in fossil fuel related businesses.

Figure 10: Estimated consumption of oil, coal, and natural gas in Japan



Source: NGFS scenarios (2nd edition) (prepared by the FSA and BOJ)

② Power Sector

The power sector differs from the energy sector in that the NGFS scenarios do not anticipate electricity business to decline in the transition to carbon neutrality. Rather, the ongoing shift from fossil fuels to electricity in the secondary energy mix will increase electricity consumption both globally and in Japan. In addition, the power generation from renewable energy sources, such as wind and solar power, is projected to increase, while dependence on thermal power generation in Japan—which at present accounts for around 80% of the power mix—is projected to gradually decline (left side of Figure 11).

In the Net Zero 2050 scenario and the Delayed transition scenario, electricity prices are expected to fluctuate significantly, reflecting the projected changes in the power mix and associated power generating costs—namely, new capital investment to increase renewable energy generation and increases in fuel prices (right side of Figure 11).[16]

[16] Electricity prices in the NGFS REMIND model are set based on the lump-sum cost of generation, which accounts for whole capital investment at a time. Some participants, however, pointed out that such method is not necessarily consistent with Japan's system, where electricity prices are set based on depreciation for fixed assets.

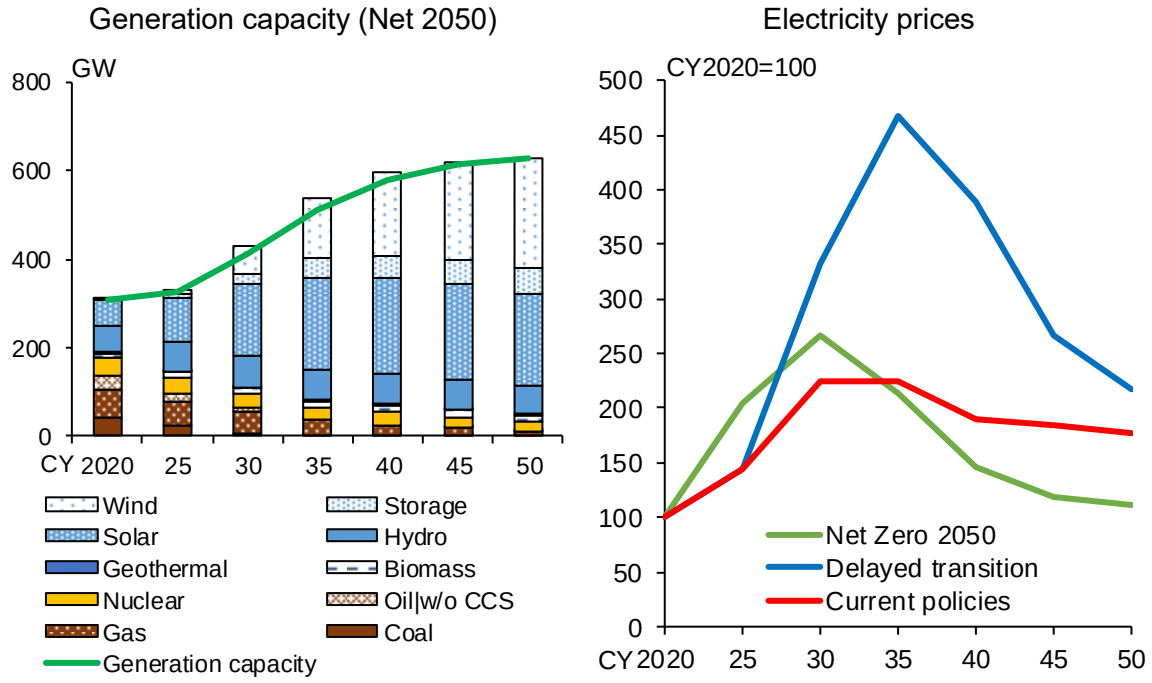
The banks constructed their models and estimated credit costs based on the above outlook for the power sector. Key parameters in the model include projected changes in the power mix, electricity prices, fossil fuel prices, investment costs for renewable energy, and carbon price burdens from fossil fuel use.

The results showed that the estimated transition risk credit costs of the power sector are significantly smaller than those of the energy sector. This is likely because, although capital investment for renewable energy power generation may increase interest-bearing debt, its cost is largely passed on to electricity prices, so the levels of profits do not drop significantly, unlike in the energy sector.

On the other hand, like in the energy sector, the estimated results varied among the banks, reflecting differences in their model characteristics and the key assumptions: the extent to which power generation costs are passed on to electricity prices and the magnitude of expected increase in interest-bearing debt associated with capital investment for renewable energy power generation.

Note that in this analysis the participating banks did not take into account the impact on the other sectors of electricity price increases in the NGFS scenarios, which reflect investment costs for renewable energy.

Figure 11: Japan's power supply mix assumptions (based on generation capacity) and electricity prices



Source: NGFS scenarios (2nd edition) (prepared by the FSA and BOJ)

③ Steel and automotive sectors

Steel and automobile sectors are, as in other sectors, expected to reduce greenhouse gas emissions in the production and consumption stage in the transition to carbon neutrality. For example, the steel sector is developing hydrogen reduction steelmaking technology to lower carbon emissions. The automobile sector is shifting its production from internal combustion engine (ICE) vehicles to electric vehicles and fuel cell electric vehicles.

The NGFS scenarios, however, lack projections of key variables that could have a significant impact on the analysis. For the steel sector, the NGFS scenarios only provide projections of steel production in each country, but no breakdowns by production method, such as hydrogen reduction steel production. Likewise, NGFS scenarios do not provide projections of automobile production by power type, such as ICE vehicles and electric vehicles.

As such, the participating banks instead used information from the government, international agencies, and industry associations to make

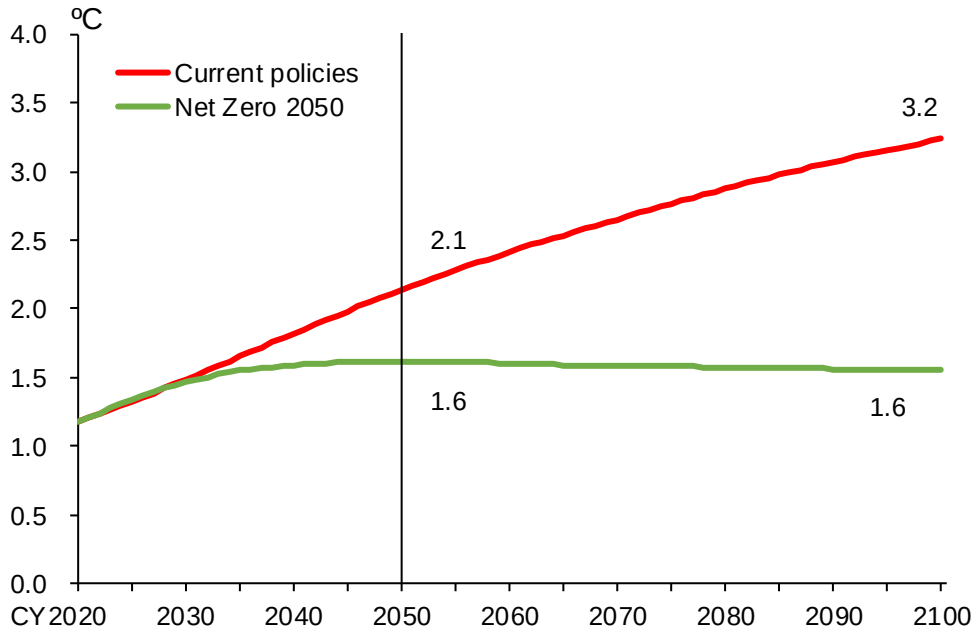
projections of the key variables under the NGFS scenarios. However, the results differ significantly among banks, to a greater extent than those for the energy and power sectors, due to the large divergence of views in each sector's transition pathways as well as the differences in the credit cost estimation models and the variables used. Therefore, how to ensure the validity and comparability of the data independently collected by banks remained a challenge.

(2) Physical risk

Physical risk was assessed mainly as the difference in estimated cumulative credit cost increases between the two scenarios: the Net Zero 2050 scenario with the lowest temperature rise and the Current policies scenario with the highest temperature rise ("estimated physical risk credit costs"). The levels of cumulative credit cost increases did not differ significantly from those disclosed by the participating banks in their TCFD Reports, as in transition risk. The increases were driven mainly by the suspension of business activities due to the disasters and to a lesser extent by collateral damages.

Average annual increases in estimated physical risk credit costs up to 2100 is several times larger than those up to 2050. This is because, as shown in the diagram below, the difference in temperature in the two scenarios is expected to widen from about 0.5°C in 2050 to about 1.6°C by 2100 and so is the risk of severe disaster.

Figure 12: Global mean temperature increase by scenario (vs. 1850 -1900 average)



Source: NGFS scenarios (2nd edition) (prepared by the FSA and BOJ)

Regional results by the one participating bank showed that credit cost increases tended to be higher in large cities with concentrated exposures, partly reflecting the limitations on data availability about important business unit locations of borrowers, such as business offices and plants.

IV. Financial risk analysis in insurance

1. Analytical framework and models used

(1) General

In this scenario analysis of non-life insurance groups, we focused on physical risks (acute risks by typhoons and floods) related to their underwriting business, taking into account the importance (impact) of risks to non-life insurance groups. As with banks, we adopted a bottom-up approach, in which non-life insurance groups conducted analysis based on the scenarios prepared by FSA. In this approach, non-life insurance groups assessed the amount of their claim payments using the risk models[17] that they actually used to measure the risk amount.

All risk models used in analysis are based on past disasters without taking into account the impact of future climate change. Therefore, by using the scenarios with intensified magnitude of specific disasters, it is possible to grasp the magnitude of physical risks (as changes in insurance claim payments) under conditions considering the impact of future climate change.

As for the method of intensifying magnitude of specific disasters, assumed disasters (typhoons and floods) are set based on the temperature rise projections in the NGFS scenarios, with reference to various studies on climate change. The two scenarios used in this analysis are net 2050 and current policies, which show characteristic temperature changes. The scope of analysis includes 2050 and 2100, since the effect of physical risks gradually appears over a long period of time.

Other assumptions were unified as much as possible (e.g., future variable factors, such as strength of embankments and buildings, number and portfolio of contracts are fixed at current conditions).

(2) Typhoon risk

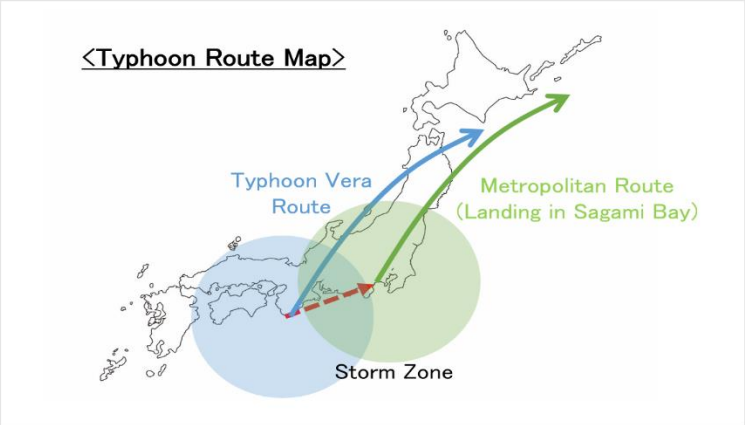
We picked up Typhoon Vera as a sample typhoon. For Typhoon Vera (intense typhoon with the intensity of one that hits once in 70 years that hit Ise Bay in 1959), which is the risk measurement standard under the current solvency margin standard,[18] the central pressure was lowered in several patterns based on

[17] A tool for measuring the amount of risk, which includes a large number of scenarios (disasters) in a risk model and can simulate the amount of damage if they occur.
[18] Criteria for whether the state of solvency in terms of ability to pay insurance claims, etc. is appropriate.

future projections in the scenarios.

There are two routes: (1) the "Typhoon Vera original Route," which is the same as previous landings; and (2) the "Metropolitan Route," which is shifted eastward to hit the Tokyo metropolitan area.

Figure 13: Typhoon routes used in scenario analysis



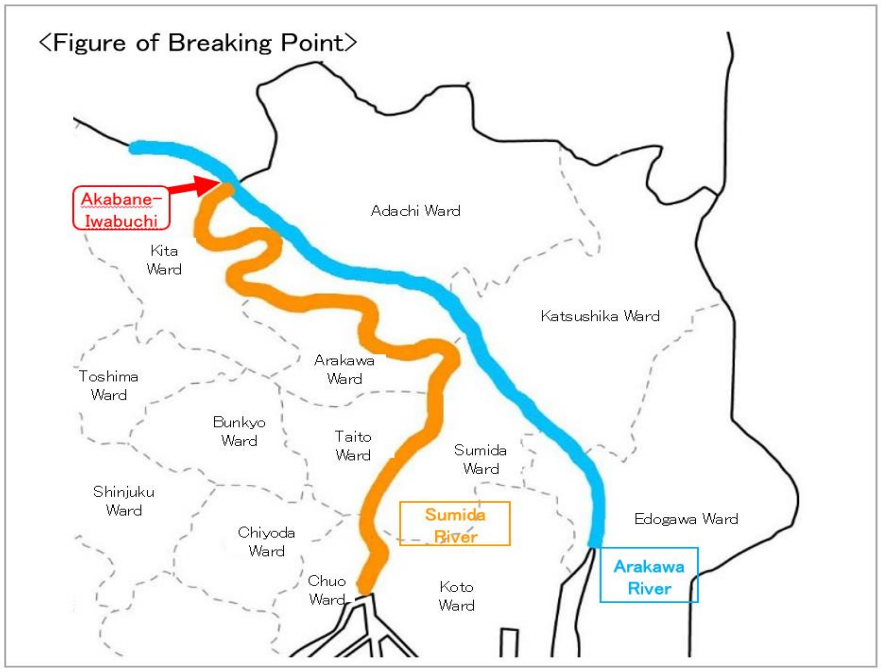
(3) Flood risk

For external flood,[19] we picked up a sample scenario from the scenarios in each group's risk model, the one that was closest to the Arakawa River flooding scenario (which would record a heavy loss equal to that of a flood that hits once in 200 years) was selected, and the amount of rainfall and river flow were intensified based on future projections.

The analysis was based on the assumption that the 21.0 km point on the right embankment of the Arakawa River (Akabane-iwabuchi[20]) would be breached.

[19] The houses are submerged due to the breaking of an embankment or overflow of a river.
[20] One of the typical break points used by the Ministry of Land, Infrastructure, Transport and Tourism in its Arakawa river flood assumption.

Figure 14: Breaking point used in scenario analysis



2. Results and Key Issues

The results and key issues related to typhoons and floods are as follows:

(1) Typhoons

- Claim payments increased as central pressure dropped, with a larger increase per year between 2050 and 2100 than between 2021 and 2050.[21]
- In addition to the difference in risk models, there were some inconsistencies in assumptions among three insurance groups, such as the method of setting the typhoon radius (fixed or extended) when the central pressure is lowered. As a result, the amount of claim payments varied by groups.
- Each parameter (e.g. wind speed) automatically calculated within the risk model based on assumptions are highly sensitive to claim payments, and even a slight difference in assumptions can have a significant difference on the results.

[21] It should be noted that these results are based on the current assumptions (central pressure, typhoon route, etc.) and may vary under different assumptions.

(2) Floods

- Claim payments increased as rainfall and river flow intensified.
- In this analysis, the results were affected by the topography of the flooded area in addition to the fact that the analysis was conducted on the assumption that the embankment would break at a certain point. Therefore, there was an insignificant impact on the flooded area, even if rainfall and river flow intensified. As a result, the change in projected claim payments was smaller than that of the typhoon.
- In addition to the difference in risk models, loss amounts were sensitive to spatial and temporal rainfall distributions (place, amount and length of time) even with the same precipitation and river flow. Furthermore, the metric of "a disaster that hits once in 200 years" could be recognized differently, such as precipitation, river flow, loss amount etc. As a result, insurance claim payments varied by group.
- Although technical limitations still exist, there are also limits to the accuracy of analysis based on the assumption that an embankment will break, because floods do not occur until it breaks, and once it breaks, the damage will rapidly expand.

Given the above key issues, further enhancement is required for the following reasons in order to realize the ideal scenario analysis.

- Results tend to vary due to differences in risk models and limitations in the uniformity of assumptions.
- An analysis sampling a specific scenario (disaster) cannot capture changes in the probability of occurrence (frequency of disaster occurrence) in the future.

Therefore, in order to enhance the analysis, it is desirable that all companies use the same risk model and conduct stochastic analysis for all scenarios (e.g., tens of thousands of scenarios), including future climate change impacts, taking into account the probability of occurrence of the scenarios.

V. Future direction

The exercise revealed many challenges in analytical methods and data availability for the climate-related scenario analysis. To utilize the scenario analysis in business strategy development and risk management, financial institutions need to further enhance the methodology, including addressing the issues identified in the exercise, taking into account their risk profiles as well as international discussions and developments in practice.

The application of a scenario analysis in engagement with clients to support addressing climate change would require banks to refine their analysis of individual companies. In the course of refinement, banks may need to consider the impacts of structural changes in related industries on individual companies as well as the effects of business transformation by individual companies with banks' engagement.

Regarding insurance, the FSA will promote discussions that risk models owned by the General Insurance Rating Organization of Japan[22] can be utilized for scenario analysis by all property insurers, from the viewpoint of unifying risk models used and upgrading to stochastic analysis.

Also, since the analysis is based on long-term future scenarios, to use a scenario analysis for more convincing decision making, financial institutions need to make efforts to deepen mutual understanding with stakeholders about their outlooks and the background to their differences, based on the common understanding that uncertainty remains even with sophistication and refinement.

Going forward, the FSA and BOJ will continue dialogue with financial institutions on methods and practical application of the scenario analysis, including on how to address the issues identified in the exercise. The FSA and BOJ will also contribute to the improvement of standard scenarios and international data initiatives, including through sharing the issues identified in this exercise with central banks and supervisory authorities at international forums.

[22] An organization established under the "Act on Non-Life Insurance Rating Organization" to calculate and provide reference loss cost rates that can be some components for pricing fair premium rates of non-life insurance products.