HONG KONG MONETARY AUTHORITY
香港金融管理局

2023-2024 BANKING SECTOR CLIMATE RISK STRESS TEST

CONTENTS

EXECUTIVE SUMMARY

Introduction

The global economy including the financial industry faces increasing threats from climate change with widespread damages and disruptions caused by extreme climate events. In the light of these escalating challenges, and alongside international efforts to limit global warming by reducing carbon emissions, the Hong Kong Monetary Authority (HKMA) undertook climate risk stress test (CRST) to assess the climate resilience of the Hong Kong banking sector and facilitate the capability building of the industry in measuring and managing climate risks. Drawing on the experience gained and the industry feedback on the pilot exercise in 2021, the HKMA launched the second round of the CRST (CRST 2.0) with an enhanced framework, and which was completed recently with the strong support from the industry.

A total of 46 banks, including 21 locally incorporated banks and 25 branches of international banking groups, participated in the CRST 2.0 exercise. These institutions as a whole accounted for 91% of the banking sector's total lending or 86% of the sector's total assets as of end-December 2022. Not only has this extensive participation ensured the representativeness of the assessment results, it has also demonstrated the strong commitment of the Hong Kong banking industry to the proactive development of climate risk management capabilities.

Stress scenarios

The CRST 2.0 comprises two sets of complementary stress scenarios:

- Short-term scenario: A newly developed scenario featuring simultaneous climate-related shocks and an economic downturn, with a 5-year assessment horizon from 2023 to 2027; and
- Long-term scenarios: The Below 2°C, Delayed Transition and Current Policies scenarios adopted from the Network of Central Banks and Supervisors for Greening the Financial System (NGFS), representing an orderly transition, disorderly transition and "Hot house world" respectively, with an assessment horizon from 2023 to 2050.

Assessment results

The results indicate that **the Hong Kong banking sector continues to demonstrate strong resilience against severe climate-related shocks under various stress scenarios, including the one assuming a simultaneous economic downturn.**

Short-term scenario

The combined macroeconomic and climate-related shocks are projected to cause the total capital adequacy ratio (CAR) of the banking sector to drop by 1.4 to 3.1 percentage points (ppts). The stressed CAR at the lowest point (i.e. 16.6%) during the assessment horizon would remain well above the international minimum requirement of 8%. As the economy bottoms out from the initial shocks, the negative impact of climate risks would be offset gradually and the industry CAR at the end of the assessment horizon would be 1.4 ppts lower than the pre-stressed level.

Long-term scenarios

The results suggest that the Below 2°C scenario (i.e. orderly transition) is relatively favourable to banks in the long run. Compared to the other two scenarios, an orderly transition would cause banks to incur a higher level of credit costs during the initial years of the assessment horizon. However, the participating banks project that the situation would reverse after 2030 and the relative benefits of orderly transition would continue to increase towards 2050.

Capability building

Banks have strengthened their stress testing capabilities for evaluating the impact of climate risks. With their continuous efforts dedicated to this endeavour, the HKMA observed a number of good industry practices in CRST 2.0 covering a range of areas, including but not limited to model governance, data collection and processing, as well as granularity of assessment and methodologies.

Many participating banks have strengthened their governance framework notably for conducting the CRST. In particular, some banks which leveraged the expertise of third-party vendors have put in place a robust framework for evaluating the reliability of models developed by the latter and assessing the applicability of these models to their portfolios before using them for risk assessment.

Some participating banks have showcased the benefits of adopting advanced technologies for the CRST. The use of artificial intelligence in data collection, for instance, has enabled the banks concerned to harness a vast amount of information for analysing the impact of climate risks efficiently. On assessment methodologies, many banks have shifted towards more scientific approaches, such as utilising climate models to simulate the frequency, intensity and damages of climate hazards. This forward-looking approach has complemented analyses based on historical data and provided valuable insights into the banks' exposure to climate risks especially under the long-term scenarios.

The advancements observed from CRST 2.0 indicate that the banking industry has attached growing importance to climate risk management. They have also contributed to more comprehensive and reliable CRST results.

Way forward

The HKMA will continue to provide supervisory guidance and feedback to the industry, supporting banks' efforts in climate-related risk management under the Sustainable Finance Action Agenda. Leveraging the experience of CRST 2.0, a major short-term target of the HKMA is to optimise the integration of climate risks into its supervisor-driven stress testing (SDST) framework so that banks would assess climate-related shocks in their regular stress tests, thereby minimising the duplications for banks to conduct CRST separately.

1. INTRODUCTION

In response to the increasing threats from climate change, the Hong Kong Monetary Authority (HKMA) undertook a pilot sector-wide exercise on climate risk stress test (CRST) in 2021 to assess the climate resilience of the Hong Kong banking sector and facilitate the capability building of the industry in measuring climate risks. Drawing on the experience gained from the pilot exercise and the industry's feedback, the HKMA has enhanced the CRST framework and conducted the second round of the CRST exercise (or CRST 2.0) during 2023 to 2024 as part of its supervisor-driven stress test (SDST).

The key enhancements made to the CRST framework include the introduction of a new short-term scenario featuring both climate-related shocks and an economic downturn, refinements to scenario parameters, and standardising the industry classification of obligors and reporting metrics. With the enhanced CRST framework and continuous developments of the financial industry in gauging climate risks, CRST 2.0 seeks to obtain a more comprehensive assessment of the climate risks faced by the Hong Kong banking sector and boost further banks' climate risk management capabilities.

The key features of CRST 2.0 are as follows:

(i) The participating banks were requested to perform assessments under two sets of complementary scenarios:

- A short-term scenario with an assessment horizon from 2023 to 2027, featuring both climate-related shocks and an economic downturn; and

- Three long-term scenarios with an assessment horizon from 2023 to 2050, adopted from the Network of Central Banks and Supervisors for Greening the Financial System (NGFS) and representing an orderly transition (i.e. Below 2°C), a disorderly transition (i.e. Delayed Transition) and a "Hot house world" with an elevated level of physical risk (i.e. Current Policies) respectively.

(ii) Banks were assumed to maintain static balance sheets over the assessment horizons under both the short-term and long-term scenarios. The participating banks might consider adjusting their portfolio mix in their assessments under the Below 2°C and Delayed Transition scenarios only if they had already established clear climate strategies with measurable commitments or goals on transition.

(iii) Banks were assumed to continue to distribute dividends at a ratio of their net profit comparable to their historical average.

(iv) Compared with the pilot exercise, a broader set of scenario variables and assumptions, including sectoral impacts and macroeconomic indicators, were provided to banks participating in the CRST 2.0 exercise.

The industry was supportive of CRST 2.0, with a total of 46 banks participating in the exercise. These institutions included 21 locally incorporated banks and 25 branches of international banking groups (see Annex A). They in aggregate accounted for 91% of total lending or 85% of total assets of the Hong Kong banking sector as of end-2022. This extensive participation has ensured the representativeness of the assessment results and demonstrated the strong commitment of the Hong Kong banking industry to the proactive development of climate risk management capabilities.

The HKMA considers collaborative efforts are essential for promoting the overall standards and capabilities of the banking sector as a whole. It therefore maintained regular communication with the participating banks throughout the exercise to support them in conducting the assessment. In addition, the HKMA organised discussion forums in November 2023 and February 2025 respectively, with the aim of providing a platform for knowledge and experience sharing amongst the participating banks. More than 600 practitioners attended the forums and benefited from the discussions with the industry experts from banks, research institutions and consulting firms on how they tackled the challenges encountered in conducting the CRST. To further support the development of CRST capabilities of banks, the HKMA has identified good practices adopted by the participating banks and shares these practices in this report and in the February 2025 forum for banks' reference.

The remaining part of this report is structured as follows: Chapter 2 outlines the scenarios covered in the CRST 2.0. Chapter 3 presents the compositions of exposures assessed for physical and transition risks. Chapters 4 presents the assessment results. Chapter 5 summarises the assessment approaches and good practices adopted by the participating banks. Chapters 6 and 7 discuss the capability building of banks observed from the exercise and way forward respectively. The annexes provide the list of the participating banks, a case study and some useful references considered by the participating banks for assessing the impact of climate risks.

2. SCENARIOS COVERED

The CRST 2.0 exercise comprises two sets of scenarios with different assessment horizons[1]. The short-term scenario is a bespoke scenario combining climate-related shocks and macroeconomic shocks, while the three long-term scenarios are developed based on a subset of the third vintage of the scenarios published by NGFS[2]. Key risk drivers of these scenarios are summarised in Table 1 below. It should be emphasised that these scenarios are not the HKMA's forecasts of climate change, economic developments or their consequential effects in the future. They are hypothetical and designed specifically to evaluate the banking sector's resilience to "tail events", which could be unlikely to occur. The assumptions for some of the key drivers under these scenarios are made deliberately severe for the participating banks to quantify the "tail" risk of these low-probability events, rather than the most plausible outcomes.

Table 1: Key risk drivers of the CRST 2.0 scenarios

<table>
<tr><th colspan="2">Scenario and assessment horizon</th><th>Climate risk drivers</th><th>Macroeconomic risk drivers</th></tr>
<tr><td colspan="2">Short-term
2023-2027</td><td>▪ More frequent occurrences of extreme climate events
▪ Accelerated transition to a low-emission economy</td><td>▪ Global economic downturn
▪ Hong Kong in recession
▪ Slowdown in Mainland China</td></tr>
<tr><td rowspan="3">Long-term
2023-2050</td><td>Below 2°C</td><td>▪ Progressive transition in an orderly manner</td><td rowspan="3">▪ No additional macroeconomic risk drivers</td></tr>
<tr><td>Delayed Transition</td><td>▪ Slow transition in initial years, with accelerated transition after 2030 (i.e. disorderly transition)</td></tr>
<tr><td>Current Policies</td><td>▪ Transition limited to that brought about by policies implemented before end-2022
▪ Significant changes in climate patterns with more extreme climate events (i.e. "Hot house world")</td></tr>
</table>

[1] More details can be found in the HKMA Guidelines for Banking Sector Climate Risk Stress Test: https://www.hkma.gov.hk/media/eng/doc/key-information/guidelines-and-circular/2023/20230421e1a1.pdf

[2] Specifically, scenario variables for CRST 2.0 are developed based on those adopted from the NiGEM NGFS v1.22 model (configuration: REMIND-MAgPIE 3.0-4.4), with adjustments made for reflecting the macroeconomic developments in 2022 and 2023.

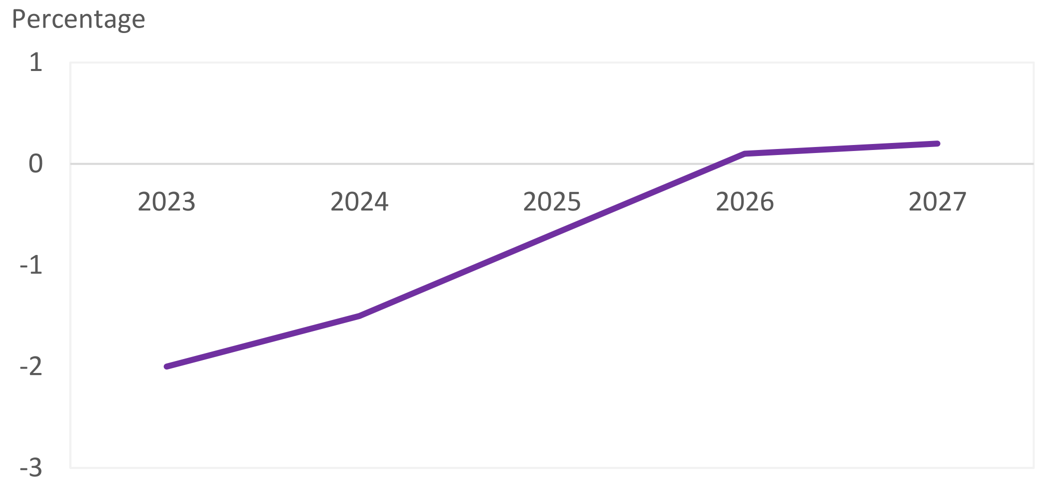
2.1 Short-term scenario

The short-term scenario features both a downturn in the global economy and policy actions for an accelerated transition amidst more frequent occurrences of extreme climate events.

Macroeconomic risk

Under the scenario, Hong Kong would slip into a recession while the economic growth of Mainland China would slow down significantly. The economic doldrums and high interest rates would lead to a substantial correction in the residential property prices of Hong Kong over the 5-year assessment horizon. Unemployment rate in Hong Kong would continue to climb alongside the deterioration of the economic situation. The asset quality of the Hong Kong banking sector would worsen as a result. Chart 1 depicts the pathway of real gross domestic product (GDP) growth of Hong Kong over the assessment horizon. It should be noted that the macroeconomic shocks are very severe, as the Hong Kong economy contracted by 3.7% in real terms in 2022 and the economy is assumed to shrink further in the next 3 years and not to exhibit a subdued recovery until 2026.

Chart 1: Year-on-year real GDP growth of Hong Kong under the short-term scenario



Source: HKMA

Physical risk

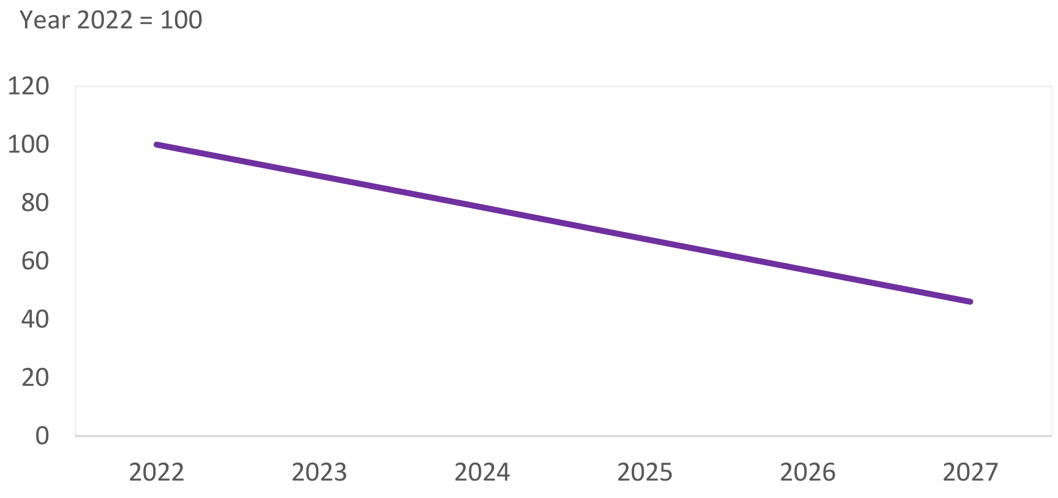
During the 5-year assessment horizon, heavy precipitation and severe tropical cyclones in Hong Kong causing damages to properties would occur more often than those observed historically. A number of extreme climate events are assumed for each year between 2023 and 2027.

It is assumed in the short-term scenario that climate hazards in Mainland China in each year of the assessment horizon are comparable to the extreme precipitation and heatwave experienced in 2021 and 2022 respectively. These climate hazards would mainly manifest their impacts in damages to physical assets, and disruptions to business activities and industrial production.

Transition risk

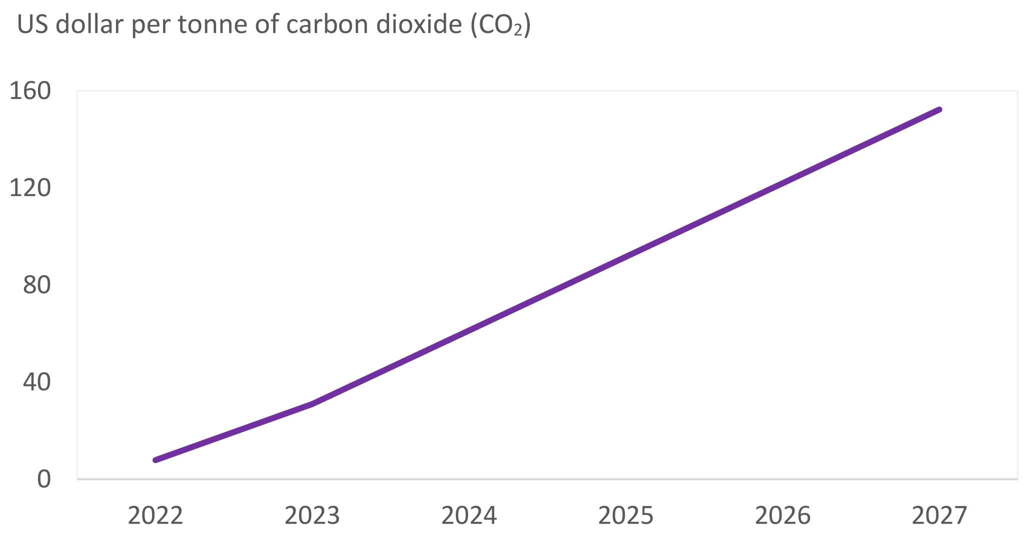
The transition policies in major jurisdictions including Mainland China would lead to a spike in carbon price and provide incentives to corporates to transit to low-emitting business models. Corporates involved in high-emitting activities would be adversely affected by both increasing operational costs and shrinking demands amidst the sluggish economic environment. There would be significant investments in renewable energies and emission reduction technologies, such as carbon capture and storage, but there would be limited breakthroughs within the 5-year assessment horizon. The phase-out of coal would be more pressing than that of oil and gas given its heavier carbon emissions. This, together with the gap between supply of green energies and power demand, would push up the prices of oil and gas throughout the assessment horizon. Notwithstanding this, carbon emissions in Mainland China would be reduced by 54% during the period. Chart 2 to Chart 4 depict the pathways of carbon emissions index and carbon price in Mainland China, and world commodity price index respectively under the short-term scenario.

Chart 2: Index of carbon emissions in Mainland China under the short-term scenario



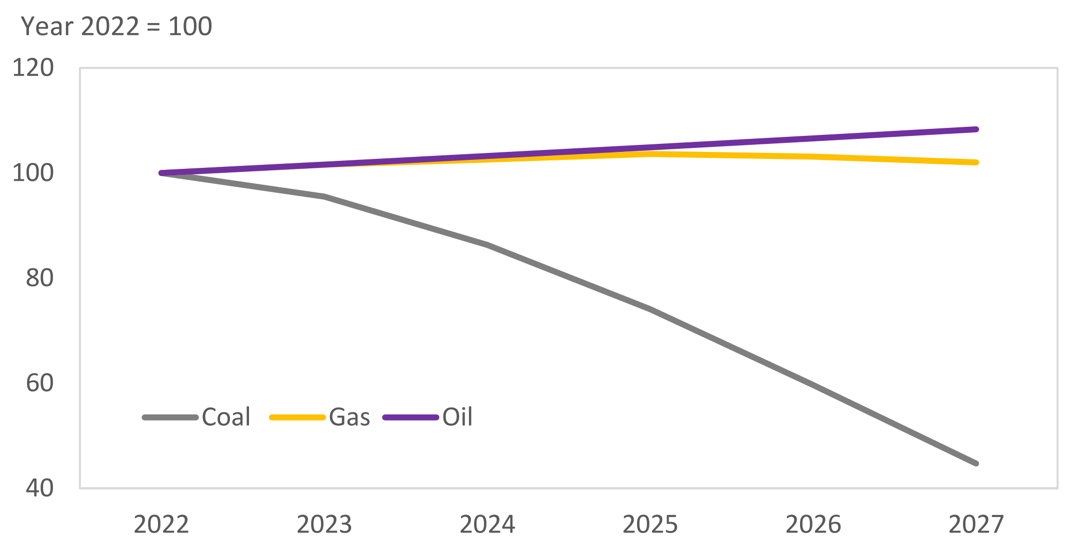
Source: HKMA

Chart 3: Carbon price in Mainland China under the short-term scenario



Source: HKMA

Chart 4: World commodity price index under the short-term scenario



Source: HKMA

2.2 Long-term scenarios

The three long-term scenarios are developed based on a subset of the third vintage of the NGFS scenarios, i.e., Below 2°C, Delayed Transition and Current Policies. Consistent with the setting of the NGFS, all jurisdictions are assumed to undertake policy actions in line with the narratives of the scenarios[3].

(i) Below 2°C: Climate policies would be introduced immediately and become more stringent gradually to achieve an orderly transition;

(ii) Delayed Transition: New climate policies would not be introduced until 2030, resulting in a disorderly transition; and

(iii) Current Policies: No new climate policy would be introduced, while policies implemented before the end of 2022 would be preserved.

Physical risk

Under the Current Policies scenario, carbon emissions would continue to increase and global warming would reach 2°C by the middle of the 21st century as compared to the pre-industrial level, leading to non-linear and irreversible adverse changes in climate patterns. To capture the potential catastrophic impacts of global warming, it is assumed that temperature increase would be having a major impact on ice sheet processes and sea level would keep on rising as a result. Hong Kong would be severely affected by the elevating global warming with the mean air temperature and sea level rising significantly. The rise in temperature and sea level, together with noticeable increases in precipitation and the number of violent tropical cyclones, would pose larger threats to Hong Kong than those of climate events observed in the past.

The impacts of physical risk under both the

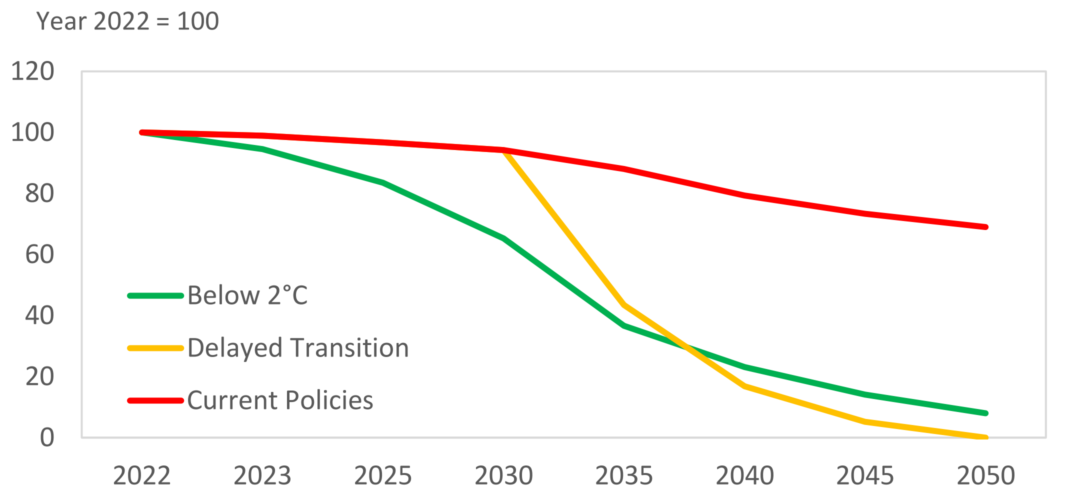
[3] More detailed descriptions of the scenarios can be found in the website of the NGFS: https://www.ngfs.net/ngfs-scenarios-portal/data-resources-phase-3/

Below 2°C and Delayed Transition scenarios would be relatively contained compared to those of the Current Policies scenario throughout the assessment horizon, partly attributable to the reduction in carbon emissions driven by the transition policies. Under the Delayed Transition scenario, however, there would be an increase in physical risk impact relative to the Below 2°C scenario after 2030 because of the deferral in taking transition actions. The increase would then gradually abate towards the end of the assessment horizon.

Transition risk

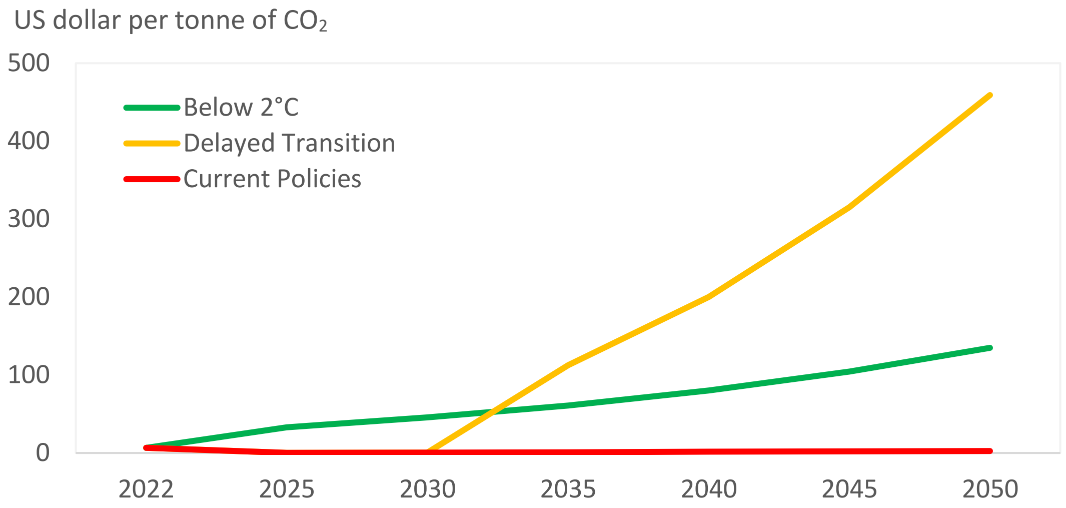
The Below 2°C and Delayed Transition scenarios share the same target of limiting global warming to below 2°C within this century as compared to the pre-industrial level. However, the Delayed Transition scenario assumes that new policies would not be introduced until 2030. From then on, a sharp increase in emission costs would be required to expedite the reduction in carbon emissions to achieve the target. Under the Current Policies scenario, movements in carbon price would be limited throughout the assessment horizon, and changes in carbon emissions and energy mix would be much more gradual than those under the other two long-term scenarios. Chart 5 to Chart 7 display the carbon emissions index, carbon price and energy mix in Mainland China under the long-term scenarios respectively.

Chart 5: Carbon emissions index in Mainland China under the long-term scenarios



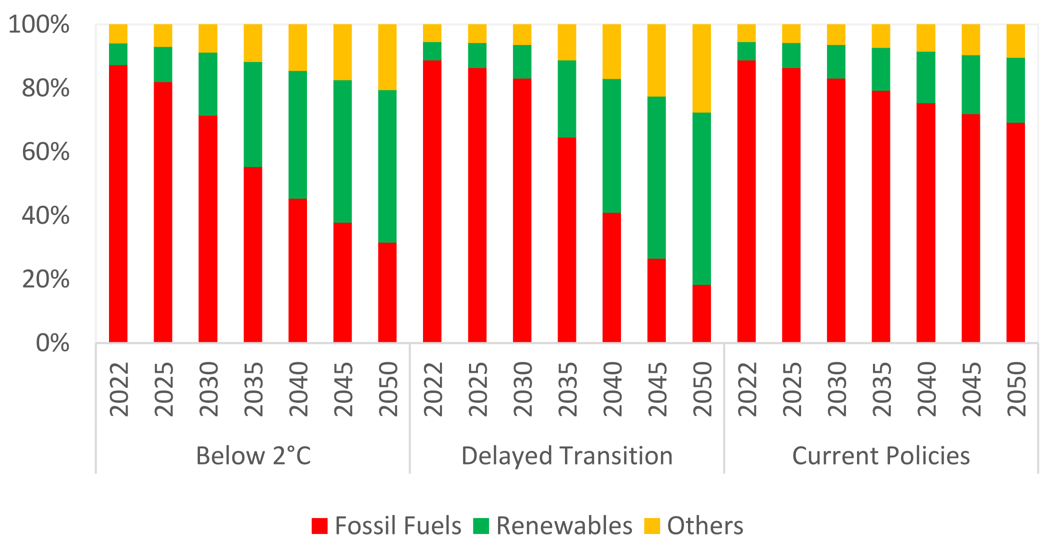
Source: NGFS

Chart 6: Carbon price in Mainland China under the long-term scenarios



Source: NGFS

Chart 7: Primary energy mix[4] in Mainland China under the long-term scenarios



Source: NGFS

[4] "Fossil fuels" includes coal, oil and gas; "Renewables" includes non-biomass renewable fuels; and "Others" includes nuclear and biomass fuels.

3. RISK IDENTIFICATION

3.1 Physical risk

Participating banks evaluated the financial impacts of climate hazards on their exposures under both the short-term scenario and the long-term Current Policies scenario. In particular, the banks were expected to cover the following exposures in their physical risk assessment:

(i) Mortgages and other types of property-related lending[5];

(ii) Banks' own property investment;

(iii) Exposures to other obligors whose credit quality would be significantly affected by extreme climate events; and

(iv) Operational losses associated with extreme climate events.

Box 1: Identification of obligors significantly affected by extreme climate events

Compared with the pilot exercise, the scope of physical risk assessment for CRST 2.0 has been significantly expanded. Specifically, the participating banks were requested to assess not only their property-related lending but also their exposures to obligors whose credit quality would be significantly impacted by extreme climate events.

Most participating banks conducted comprehensive analyses of the transmission channels through which extreme climate events (such as typhoons and heatwaves) would affect their obligors and hence the credit quality of the banks' exposures to these obligors. This involved the identification of how such events could lead to financial strain on various business sectors. The participating banks commonly assessed that the construction, tourism and manufacturing sectors would be inherently sensitive to extreme climate events.

(i) <u>Construction:</u> Construction companies might face project delays and damages due to extreme weather conditions, leading to increased costs or even completion failures.

(ii) <u>Tourism:</u> This sector would be susceptible to disruptions arising from severe weather, which could deter visitors and impact revenue streams.

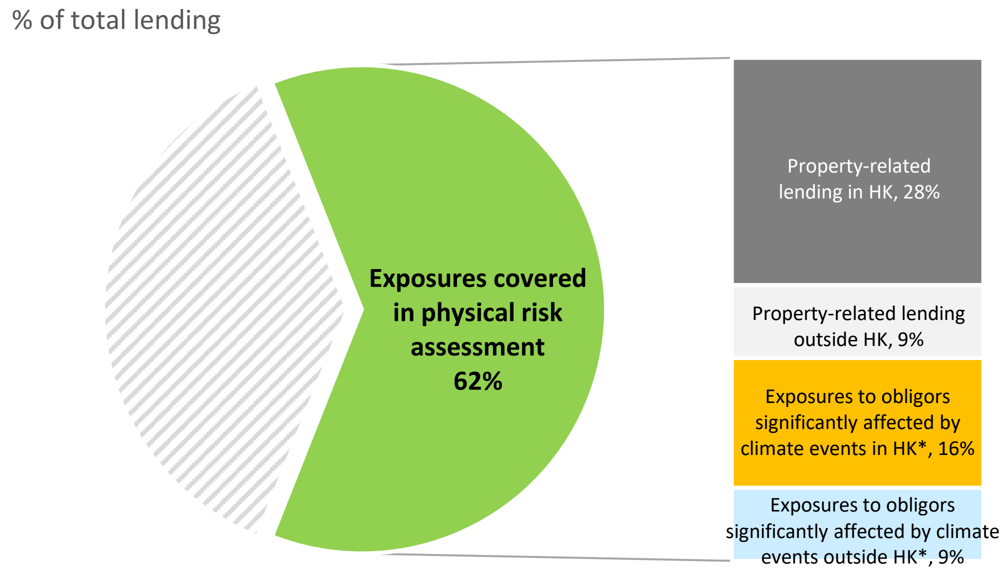
(iii) <u>Manufacturing:</u> Supply chain disruptions and operational challenges could arise from extreme climate events, affecting production capabilities and financial strengthen of manufacturing companies. In addition, high temperature could accelerate the depreciation of machinery.

[5] It refers to lending for property development and investment, and any other lending with property (properties) as collateral.

In addition to evaluating exposures within Hong Kong, the participating banks also endeavoured to assess the physical risk impact associated with their exposures outside of Hong Kong, primarily in Mainland China and Southeast Asia.

The participating banks estimated that 62% of their total lending were covered in their physical risk assessment for CRST 2.0, compared to 28% in the pilot exercise (see Chart 8). The expanded coverage has facilitated a more comprehensive assessment of climate risks.

Chart 8: Credit exposures covered in participating banks' physical risk assessment



Source: HKMA

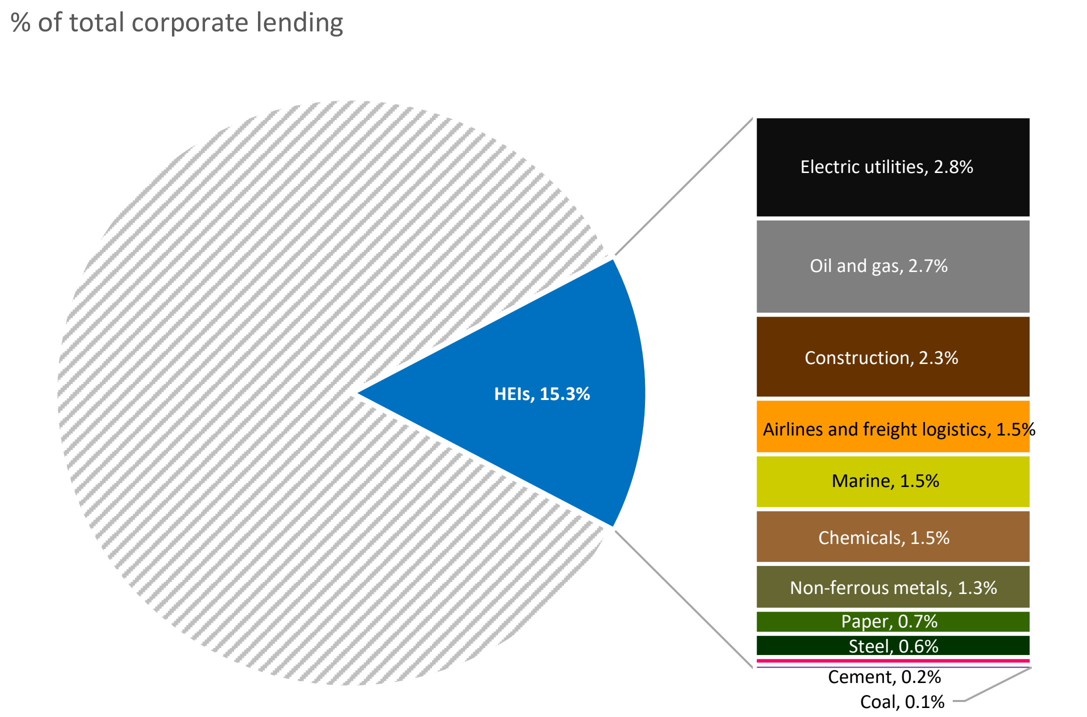
* Other than property-related lending

3.2 Transition risk

A key enhancement to the CRST framework for CRST 2.0 is the adoption of a standardised and more granular industry classification system[6]. The modified classification is more aligned with those adopted by other authorities for assessing climate risks or formulation of transition policies (e.g. Mainland China). The enhancement has facilitated a more consistent and precise transition risk assessment associated with specific business sectors within broader categories and avoided overestimation of risk.

In collaboration with major participating banks, the HKMA identified 11 business sectors for transition risk assessment. These sectors, either high-emitting industries or those which tend to be severely affected by transition policies, are collectively referred to as "HEIs" in this report. The 11 HEIs include oil and gas, coal, chemicals, cement, steel, non-ferrous metals, paper, construction, airlines and freight logistics, marine and electric utilities[7]. The participating banks' aggregate exposures to the 11 HEIs amounted to 15% of their total corporate lending (see Chart 9) or 8% of their total lending as of end-2022.

Chart 9: Exposures covered in participating banks' transition risk assessment



Source: HKMA

[6] Participating banks were required to follow the definitions of the Global Industry Classification Standard (GICS) to segment their exposures for transition risk assessment. Definitions of business sectors under the GICS can be found at https://www.spglobal.com/spdji/en/ landing/topic/gics/.

[7] Electric utilities exclude renewables and nuclear electricity for the purpose of CRST 2.0.

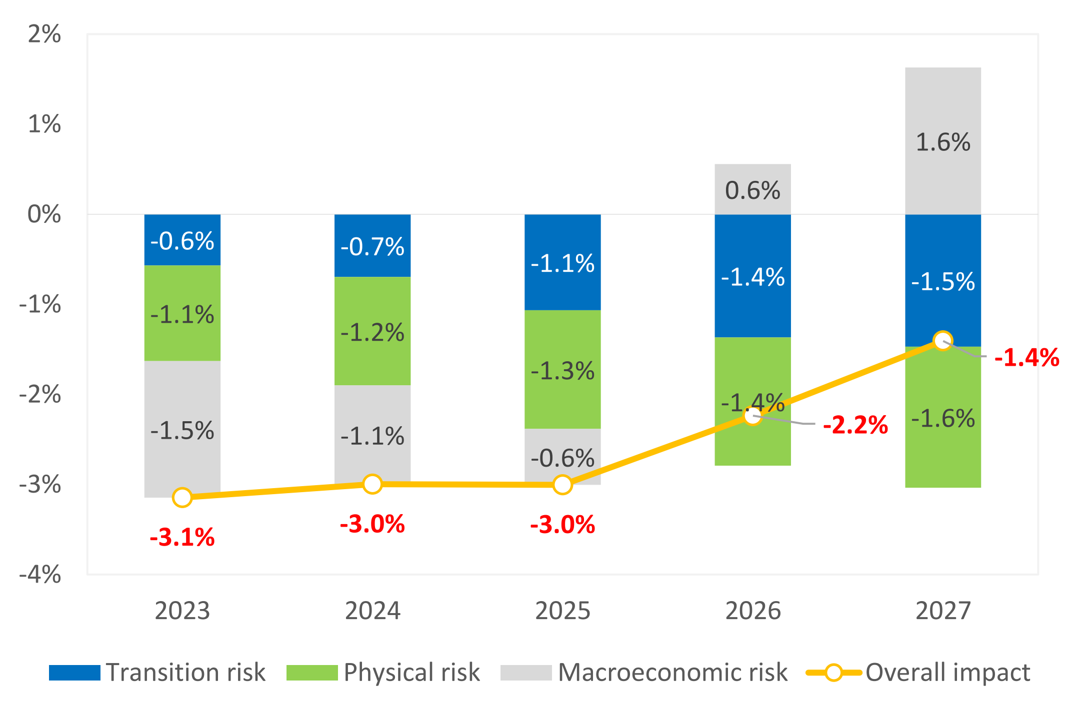
4. ASSESSMENT RESULTS

4.1 Short-term scenario

The results indicate that **the Hong Kong banking sector can withstand simultaneous shocks from climate risks and an economic downturn.** In particular, the stressed total capital adequacy ratio (CAR) of the locally incorporated banks would remain well above the international minimum requirement of 8% throughout the assessment horizon. The most significant decline in the total CAR is projected to occur in 2023, with a drop of 3.1 percentage points (ppts) as compared to the pre-stressed level as of end-2022 (see Chart 10).

Of this 3.1-ppt decline, 1.7 ppts are attributable to climate risks. The adverse impact of climate risks on the total CAR is expected to persist and increase cumulatively over the assessment horizon, reaching 3.1 ppts in 2027. As Hong Kong economy is assumed to bottom out from recession after 2025, the subsequent recovery would partially offset the negative impact of climate risks. As a result, as compared to the level at the end of 2022, the decline in the industry's total CAR is projected to narrow to -1.4 ppts by the end of 2027.

Chart 10: Stress impact[8] on total CAR (vs. end-2022) under the short-term scenario



Source: HKMA

[8] For simplicity, the impact of dividend payout is incorporated in the stress impact of macroeconomic risk in the chart.

4.1.1 Macroeconomic risk assessment

The macroeconomic shocks arising from tightening monetary policies in major developed economies would cause credit quality to deteriorate and affect banks' capital positions adversely. However, a gradual improvement is anticipated alongside the economic recovery assumed in the later years of the assessment horizon.

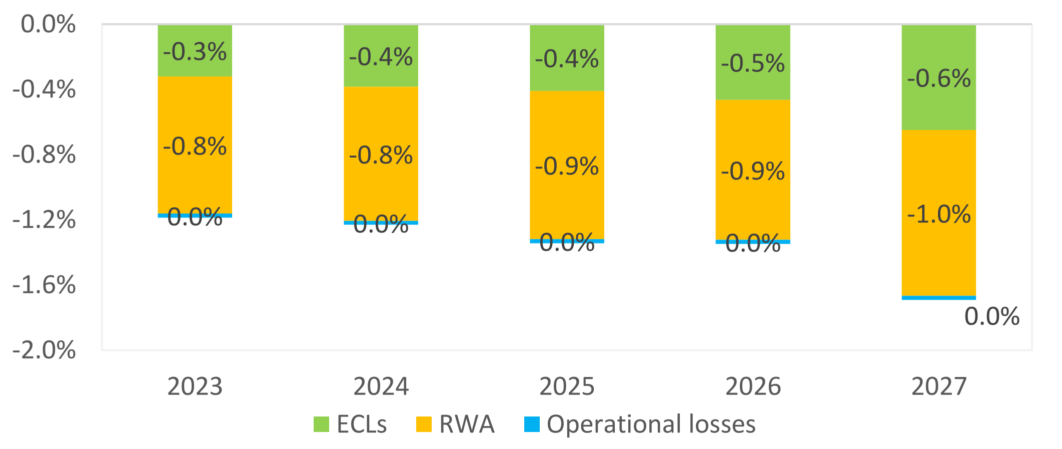
While net interest income (NII) is projected to increase due to the high interest rate environment assumed for the scenario, it would be offset by the adverse effects of worsening credit quality amidst the heavy interest burden on obligors and the sluggish economic conditions in the initial years of the assessment horizon.

4.1.2 Physical risk assessment

Extreme climate events can lead to damages to tangible assets and disruptions to business activities. This in turn affects a bank through three main channels. The first channel is the devaluation of collateral for property-related lending. The second channel is the negative impact of asset losses and business disruptions on the creditworthiness of obligors. Physical risk transmitted through both channels affects the probability of default (PD) and loss given default (LGD) (or other credit risk metrics) of the bank's borrowers and credit exposures respectively. The third channel refers to the operational losses incurred by the bank due to damages to its own premises and business disruptions.

Overall, the adverse impact of physical risk on the total CAR is estimated to increase cumulatively over the assessment horizon and reach 1.6 ppts in 2027 (see Chart 11). The increase in credit risk weighted amount (RWA) is the main driver of the impact transmitted through the first two channels. On the other hand, the banks' own operational losses are estimated to have immaterial impact as the participating banks have implemented flexible work arrangements and put in place business continuity plans to cope with various scenarios of disruptions, including but not limited to those arising from extreme climate events.

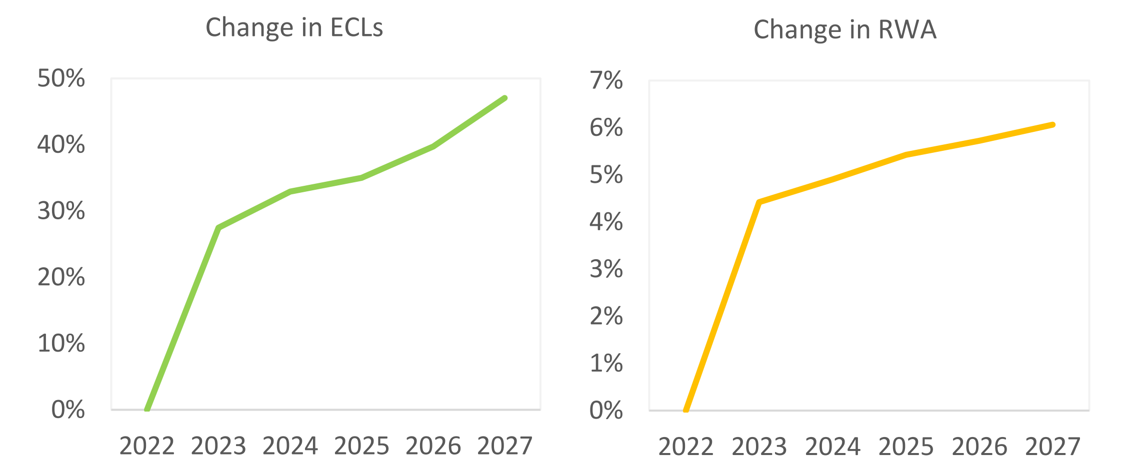
Chart 11: Impact of physical risk on total CAR (vs. end-2022) under the short-term scenario



Source: HKMA

Chart 12 shows the changes in expected credit losses (ECLs) and RWA driven by physical risk over the assessment horizon. In aggregate, the ECLs and RWA are projected to increase by 47% and 6% respectively over the 5-year assessment horizon. Many participating banks have assumed that the impact of extreme climate events would manifest not only in the years in which the events occur, but also in the subsequent years with a diminishing effect. This assumption, together with the occurrences of extreme climate events in every year during the assessment period, has resulted in the increasing trend in the cumulative impact of physical risk.

Chart 12: Changes in ECLs and RWA (vs. end-2022) driven by physical risk under the short-term scenario



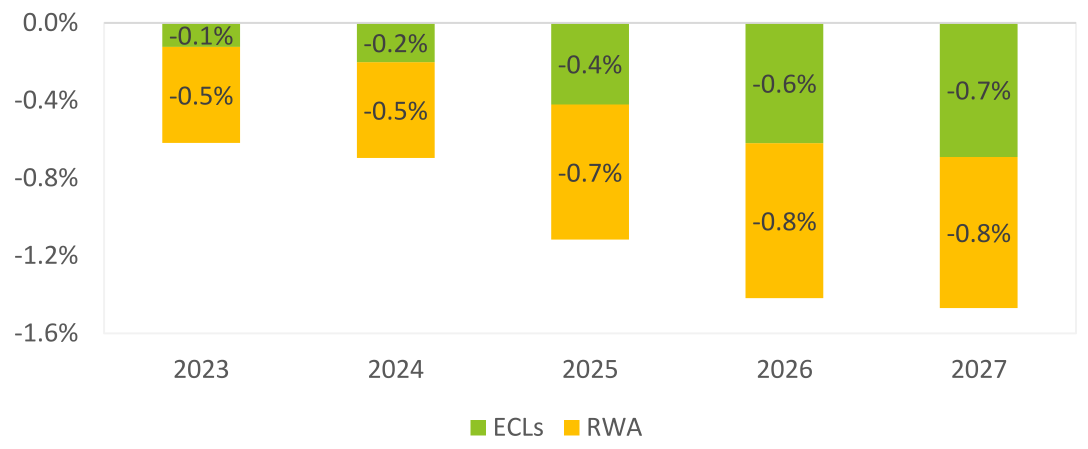
Source: HKMA

4.1.3 Transition risk assessment

Transition risk resulting from the implementation of transition policies is mainly transmitted through the PD and LGD (or other credit risk metrics) of banks' borrowers and credit exposures respectively. The participating banks assessed that the aggressive transition policies assumed in the scenario would have a relatively mild impact on their total CAR initially (-0.6 ppt in 2023, compared to -1.1 ppts for physical risk, see Chart 13). The adverse impact would increase over time at a pace faster than that of physical risk. Towards the end of the assessment horizon, the overall cumulative impact of transition risk (-1.5 ppts by 2027) would be comparable to that of physical risk (-1.6 ppts).

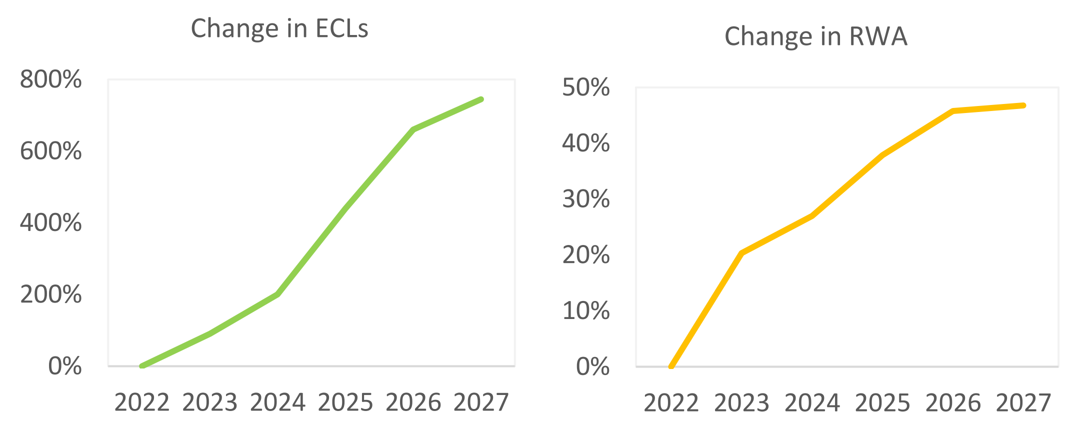
It is worth noting that aggressive transition policies would cause significant increases in the ECLs and RWA of banks' exposures to the HEIs (see Chart 14). The overall impact of transition risk on the participating banks' total CAR would remain manageable, largely because the HEI exposures did not account for a significant portion of the banks' total lending.

Chart 13: Impact of transition risk of exposures to HEIs on total CAR (vs. end-2022) under the short-term scenario



Source: HKMA

Chart 14: Changes in ECLs and RWA (vs. end-2022) driven by transition risk under the short-term scenario



Source: HKMA

The projected impact of the transition shocks on the ECLs of the HEIs exposures is particularly conspicuous. The participating banks assessed that more than 60% of the increase in the ECLs would be attributable to obligors in the sectors of electric utilities, construction, and airlines and freight logistics, which is proportional to the share of the banks' exposures to the HEIs. An exception is the oil and gas sector, which accounted for about 20% of the banks' exposures to the HEIs. The corresponding transition risk impact, however, is relatively small mainly due to the strong financial resilience that the sector has built over the years and the stable oil and gas demand assumed for the scenario.

4.2 Long-term scenarios

The HKMA did not require the participating banks to assess the physical risk impacts under the Below 2°C and Delayed Transition scenarios to avoid putting undue burdens on them. On the other hand, given the potential significant impact of the "Hot house world", the participating banks were asked to perform physical risk assessment under the Current Policies scenario for a more relevant and comprehensive evaluation with regard to the circumstances of the Hong Kong banking sector.

To facilitate an "apple-to-apple" comparison across the scenarios, the HKMA estimated the physical risk impacts under the Below 2°C and Delayed Transition scenarios based on the economic damages projected by Climate Analytics[9].

Combining the participating banks' assessments and the HKMA's estimates, it is projected that **the capital ratios of the participating banks would remain above the level at the end of 2022 throughout the assessment horizon under all the three long-term scenarios.**

The results also suggest that amongst the three scenarios, **the Below 2°C scenario is relatively favourable to banks in the long run**. Chart 15 shows the differences in the cumulative credit losses [10] under the Delayed Transition and Current Policies scenarios relative to those under the Below 2°C scenario. Although the adverse impact under the Below 2°C scenario is higher than those under the other two scenarios during the initial years of the assessment horizon, this situation would reverse after 2030 and the relative benefits would continue to increase during the remaining assessment period. At the end of 2050, the cumulative credit losses under the Delayed Transition and Current Policies scenarios are expected to be 7.7% and 8.5% higher than that under the Below 2°C scenario respectively.

The annualised credit costs[11] driven by both the physical and transition risks under the Below 2°C scenario are estimated to be 0.18%, which is lower than 0.19% projected under the Current Policies and the Delayed Transition scenarios (see Chart 16). While the results reveal only marginal differences in the annualised credit costs amongst the three scenarios, it is crucial not to overlook the more alarming cumulative longer-term implications.

In particular, the credit costs in 2050 under the Current Policies scenario is estimated to be 0.21%. This compares to 0.16% and 0.17% under the Below 2°C and Delayed Transition scenarios. Looking beyond 2050, the global warming projected under the Current Policies scenario could result in non-linear severe and irreversible climate impacts. It is very likely that the difference in the credit costs between the "Hot house world" and orderly/disorderly transition would widen further.

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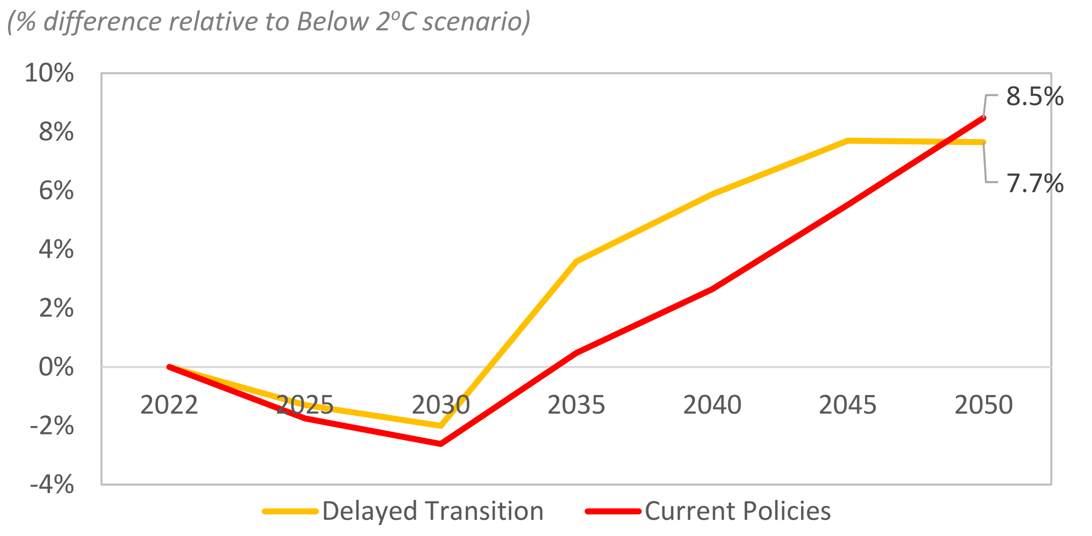
[9] Climate Analytics is a global climate science and policy institute with the mission of delivering cutting-edge science, analysis and support to accelerate climate action to limit warming below 1.5°C.

[10] "Credit losses" is defined as the sum of (i) the amount of defaulted exposures and (ii) change in ECLs of exposures covered in the physical and transition risk assessments.

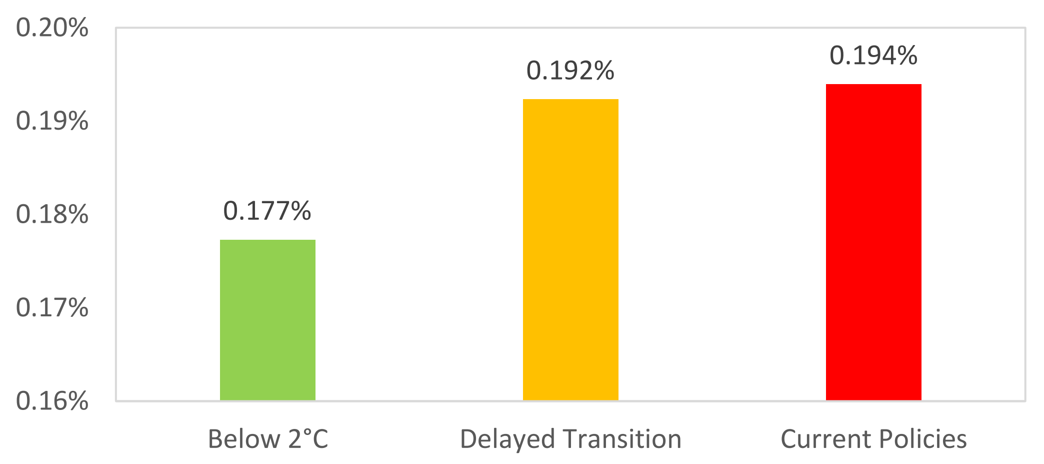
[11] "Credit costs" is defined as (i) the credit losses of exposures covered in the physical and transition risk assessments during a period, divided by (ii) total loan amount at the beginning of the period.

Chart 15: Cumulative credit losses driven by both physical and transition risks under the Delayed Transition and Current Policies scenarios



Source: HKMA

Chart 16: Annualised credit costs driven by both physical and transition risks over 2023-2050 under the long-term scenarios



Source: HKMA

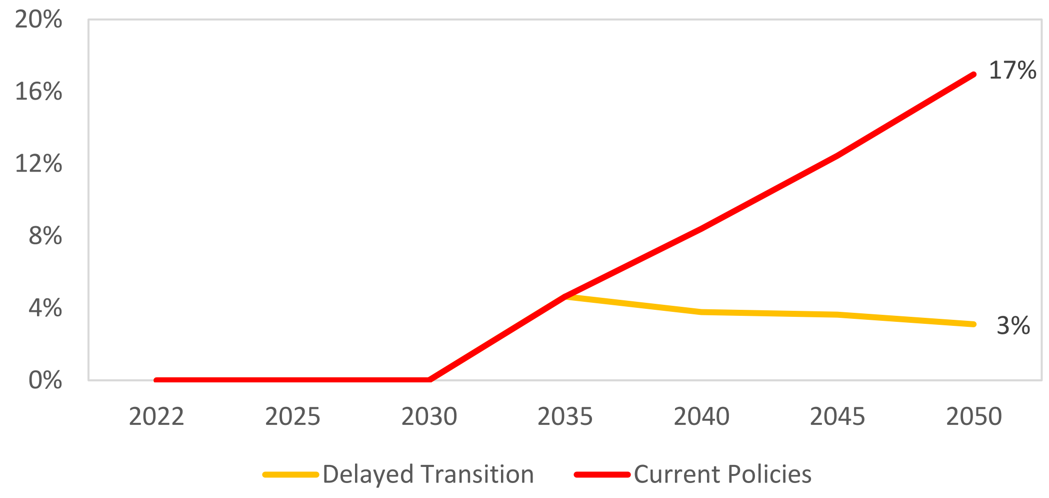
4.2.1 Physical risk assessment

Differences in the impact of physical risk under the three scenarios are projected to emerge after 2030 (see Chart 17). In particular, the effect of the measures to reduce carbon emissions on climate patterns under the Delayed Transition scenario is expected to manifest themselves gradually after 2035, and the impact of physical risk under disorderly transition would then converge with that under orderly transition towards the end of the assessment horizon.

On the other hand, the impact of physical risk under the Current Policies scenario is projected to intensify continuously.

Chart 17: Cumulative credit losses driven by physical risk under Delayed Transition and Current Policies scenarios

(% difference relative to Below 2°C scenario)



Source: HKMA

4.2.2 Transition risk assessment

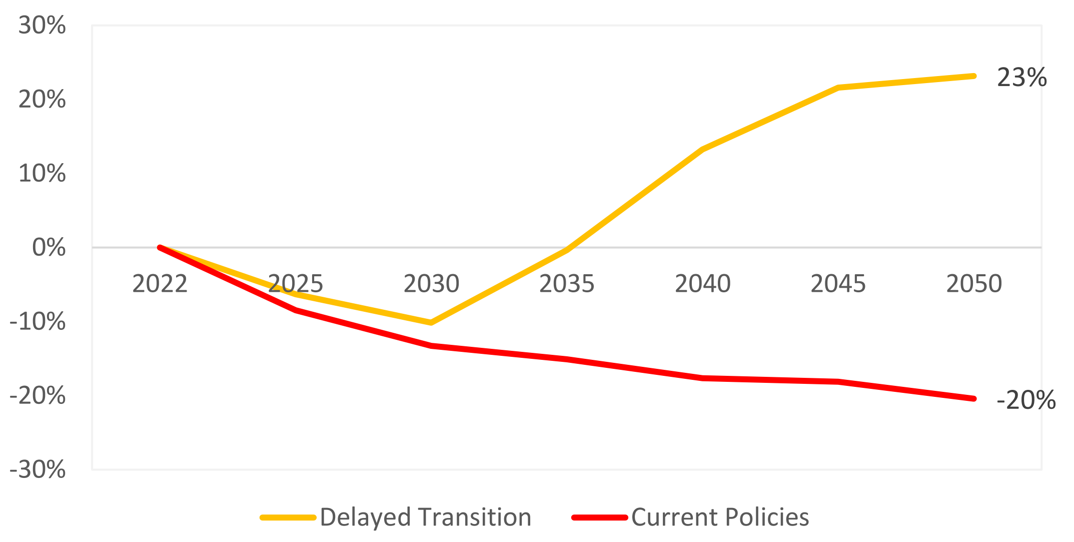
The Below 2°C scenario is estimated to give rise to higher transition costs than those under the other two scenarios before 2035, after which the accelerated actions to limit global warming under the Delayed Transition scenario would cause the transition costs to increase swiftly and exceed those under the Below 2°C scenario (see Chart 18). As compared to orderly transition, disorderly transition would cause the banks to incur an additional 23% of transition costs (in terms of credit losses) over the full assessment horizon.

The Current Policies scenario would be the least affected by transition risk as the relevant impact is limited to that brought about by policies implemented before the end of 2022. The cumulative credit losses driven by transition risk under the Current Policies scenario are projected to be 20% less than those under the Below 2°C scenario by 2050. The benefit of limited transition risk under the Current Policies scenario, however, would be outweighed by the adverse impact of the higher physical risk under the "Hot house world".

The difference in transition costs between the Delayed Transition and Current Policies scenarios is even bigger (cumulatively 55% over the assessment horizon). Again, the benefit of a smaller physical risk impact under the Delayed Transition scenario than that under the Current Policies scenario would still make the disorderly transition preferable to the "Hot house world".

Chart 18: Cumulative credit losses driven by transition risk under the Delayed Transition and Current Policies scenarios

(% difference relative to Below 2°C scenario)



Source: HKMA

The impact of transition risk on banks' exposures to the HEIs is much more severe than that to other industries. Under the scenarios of Below 2°C and Delayed Transition, the estimated annualised credit costs of exposures to HEIs are about ten times of those of other industries.

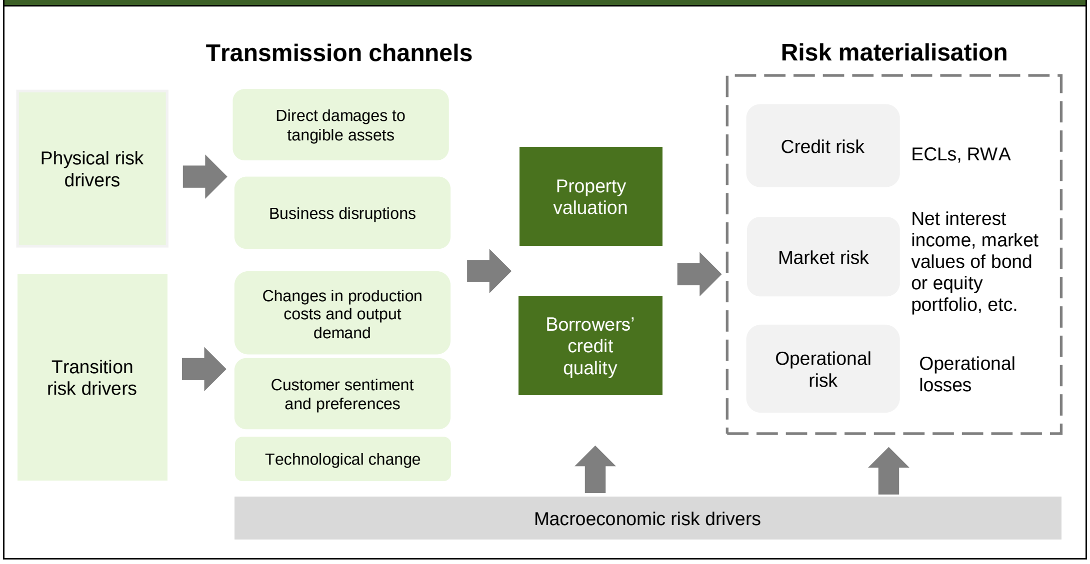
The assessment results also indicate that certain HEIs are particularly vulnerable to transition policies. These sectors typically have no commercially viable solution to lower carbon emissions in the short run, and companies in these sectors will need to invest heavily to enhance their production technology. In addition, the production costs of these companies rise with carbon price, but they may not be able to fully pass on the increased costs to their customers.

5. ASSESSMENT APPROACHES OF BANKS

5.1 Overarching framework

In general, climate risks manifest themselves in traditional financial risks, including credit risk, market risk and operational risk. To effectively conduct the CRST, most of the participating banks conducted analyses of how climate risks would be transmitted and affect their risk exposures. Depending on the analysis results, the participating banks utilised their existing stress testing models with proper modifications, or developed additional components specifically to capture climate risks based on the identified transmission channels. Chart 19 depicts a high-level view of the climate risk assessment framework adopted by the participating banks.

Chart 19: General climate risk assessment framework adopted by banks



5.2 Physical risk assessment

The physical risk assessment approaches adopted by the participating banks typically encompassed the following steps:

(i) Identify climate events: This involved assessing the occurrences of climate events along the scenario pathway;

(ii) Evaluate transmission channels: This involved establishing correlations and causal relationships between climate events and economic outcomes; and

(iii) Estimate financial impacts: This involved mapping banks' exposures to climate hazards and quantifying the associated financial impacts.

For the sake of conservatism, all participating banks did not include climate adaptation and mitigation measures (e.g. insurance renewals) in their physical risk assessments due to the uncertainty about the effectiveness of these measures.

Identification of climate events

The short-term scenario focuses on acute physical risk impacts, assuming that extreme climate events would recur every year over the 5-year assessment horizon. The long-term scenarios account for both the acute and chronic physical risks, such as sea level rise and average temperature increase, which lead to intensified climate hazards and amplified impacts along the scenario pathways.

Geographically, the participating banks' physical risk exposures were primarily concentrated in Hong Kong, Mainland China and Southeast Asia, with tropical cyclones, heatwaves, heavy precipitation and the induced flooding as the key climate hazards. A variety of approaches were adopted by the banks to project the frequency and intensity of climate hazards, ranging from a simple scaling approach based on current conditions and empirical justifications to sophisticated simulation modelling techniques (e.g. Monte Carlo).

Evaluation of transmission channels

The transmission channels through which climate hazards affect the economy would vary with the specific nature of the hazards. Tropical cyclones, heavy precipitation and the associated flooding could cause direct damages to physical assets, leading to significant repair or replacement costs and devaluation. During the occurrence of a typhoon or heavy precipitation, businesses often experience disruptions that could halt operations. On the other hand, heatwaves could pose other challenges as they could result in heat-related illnesses and increase staff absenteeism. It could interrupt business activities significantly in certain regions where outdoor work is prohibited should temperature exceed specified thresholds. In addition, the participating banks pointed out that high temperature levels could accelerate the depreciation of certain tangible assets (e.g. machinery). Asset-intensive sectors, such as manufacturing, could be particularly vulnerable to heatwaves. Collectively, these factors could lead to reduced revenues and increased operating costs, which adversely affect obligors' ability to repay their debts.

The participating banks employed various statistical methods to develop the relationship between climate hazards and their economic impacts. A common approach involved the use of established damage ratios or vulnerability curves, which have quantified the relationship between a specific peril variable (e.g. typhoon wind speed, flood depth and temperature rise during a heatwave) and the resulting loss in asset values or productivity. Most participating banks assessed the impact of chronic physical risk indirectly by estimating the changes in the intensity and frequency of acute climate events resulting from changes in climate conditions such as temperature and sea level rises. A few banks have developed models or made reference to research papers to directly assess the impact of chronic physical risk (see Box 2).

Box 2: Direct assessment of the impact of chronic physical risk

One participating bank developed a model to estimate its classified loan ratio (CLR) in response to the evolving climate patterns, including rising temperature and precipitation rate. The model incorporated geographical particulars, taking into account local climate characteristics and economic conditions. The assessment showed that changes in climate patterns could significantly affect the estimated CLR, with a more pronounced effect over time. Amongst the chronic physical risk factors analysed, rising temperature had the most substantial impact on the estimated CLR.

To gauge the impacts of chronic physical risks, several participating banks leveraged the research results published by the HKMA regarding the long-term impact of rising temperature on housing prices in Hong Kong (see item 18 of Annex C).

Evaluation of the financial impacts

The participating banks adopted various approaches to map their exposures to the risks arising from climate hazards, and the granularity of these mappings significantly affected the assessment results. Being a key variable driving the extent of potential asset damages due to climate hazards, geographical locations of risk exposures (e.g. locations of collateral for property-related lending, and production plants for manufacturing companies) were used by all the participating banks in their mappings regardless of the granularly thereof.

To identify the high-risk areas, some participating banks conducted a comprehensive geographic assessment by examining public data[12] related to storm surge and flooding blackspots, as well as damage reports on recent extreme climate hazards. Some of the banks also conducted in-depth analyses, utilising fine spatial grids and considering building attributes such as age, height and architectural type to evaluate the potential damages from climate hazards. Conversely, other banks applied a uniform damage ratio to all properties within the same geographical unit (e.g. Tertiary planning units).

In addition to assessing direct property damages, some participating banks also analysed how climate risks would affect property prices because of market perceptions (see Box 3).

Besides geographical locations, the participating banks also factored in the nature of business activities when assessing the impact of physical risk on business disruptions. For instance, tropical cyclones could pose particular challenges to business sectors that require outdoor work such as construction. The dual focus on both locations and business types has enabled the participating banks to comprehensively identify risk exposures for climate risk assessment. A few participating banks segmented business sectors based on different levels of physical work intensity. This segmentation has enabled them to more precisely project productivity losses associated with heatwaves.

Once exposures to climate hazard risks were mapped, the participating banks assessed how these risks affect borrowers'

[12] Data published by the Drainage Services Department.

repayment abilities, and hence the PD and LGD (or other credit risk metrics) of their obligors and credit exposures respectively.

All the participating banks estimated their own operational losses associated with climate hazards based on their experience of previous extreme climate events with conservative adjustments as appropriate.

Box 3: Impact of climate risks on property prices due to market perceptions

In addition to direct damages, climate risks could also affect the valuation of properties because of market perceptions. Properties exposed to higher physical risk may face price discounts due to concerns about the potential costs of repairing the damages or increased insurance premiums. The approaches adopted by the participating banks to analyse the impact of climate risks on property prices due to market perceptions include:

(i) Correlation analysis: Examining the relationship between property values in high-risk locations and the overall property price index;

(ii) Price change study: Investigating property price fluctuations in high-risk areas following extreme climate events; and

(iii) Estimation of future repair costs: Assessing the present value of future repair costs due to more frequent and extreme climate events, and deducting it from the property value by treating discounted repair costs as a proxy for assessing the impact of market perceptions.

5.3 Transition risk assessment

The transition risk assessment approaches adopted by the participating banks typically encompassed the following steps:

(i) Industry classification: This involved segmenting their corporate exposures according to business activities and identifying those exposing to transition risk;

(ii) Evaluate transmission channels: This involved identifying the transition risk drivers and understanding the way they may affect banks' obligors;

(iii) Estimate impacts on obligors' financials: This involved analysing the transition impacts on obligors' financial performance; and

(iv) Assess financial implications for banks: This involved translating the transition impact on obligors' financials into the impact on the banks' credit and market risks.

Industry classification

To facilitate comparison and aggregation of results, the participating banks were required to follow the definitions of the GICS to segment their corporate exposures based on the obligors' major activities. A few participating banks further segmented their corporate exposures based on jurisdictions in which the obligors operated in order to reflect the differences in transition policies across the jurisdictions. In addition to the 11 HEIs, some participating banks also identified the upstream and downstream industries associated with the HEIs to facilitate their second-order impact analysis (see Box 4).

Evaluate transmission channels

The key transition risk drivers and the corresponding transmission channels identified by participating banks include:

(i) Transition policies: Examples of transition policies that could affect business performance include limiting the use of fossil fuels and/or carbon emission amount, imposing carbon emission quota, etc.. These policies (including changes in these policies) may result in higher production costs and reduction in product or service demand, affecting the profitability and hence debt repayment ability of companies, especially those in the carbon-intensive sectors.

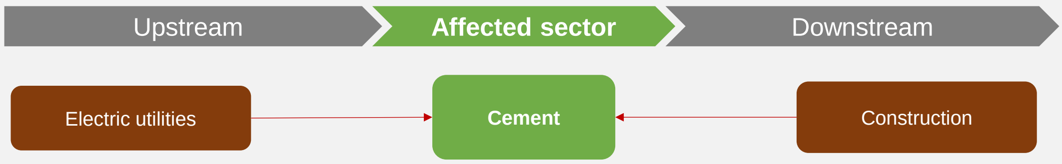
(ii) Changes in technologies: Technological innovations or advancements are essential for developing low-carbon products and services (e.g. renewable energy) to substitute existing carbon-intensive counterparts. These changes may lead to significant (if not commercially non-viable) investment costs for companies to transform into low-emission business models and reduce the demand for carbon-intensive products and services.

(iii) Changes in market sentiment: Companies' transition strategies may influence customer preferences. For example, companies perceived as environmentally responsible may gain competitive advantages, affecting market sentiment and demand for their products or services positively. In contrast, companies in the HEIs without a reliable transition strategy may face declining product or service demand.

In addition to analysing the direct transmission to the HEIs, some participating banks also analysed the second-order impact on the upstream and downstream sectors of the HEIs (see Box 4).

Box 4: Second-order impact assessment

The transition risk impacting one business sector can be spilled over to other sectors through various channels. Taking the cement sector as an example, the construction sector represents a key downstream sector because construction projects are heavily reliant on the supply of cement. Stricter regulations aimed at promoting a low-carbon economy could increase construction costs. These rising costs, driven by factors such as energy-efficient material requirements or carbon pricing, could lead to a reduction in construction activities. The decline in construction activities would subsequently reduce the demand for cement, affecting the profitability of cement manufacturers. On the upstream side, electric utilities supply the necessary power for cement manufacturing. If these utilities face increased carbon costs due to new regulations, they may pass these costs onto cement manufacturers, thereby impacting their production expenses. The construction companies and electric utility companies may also be adversely affected if, for instance, they cannot pass on the increased production costs to their customers. This illustrates the interconnected nature of value chain, where transition policies affecting one sector can have significant impact on another.



To assess these spill-over effects, banks began by analysing the interconnected relationships along the value chain of the HEIs. They identified key upstream and downstream activities to understand how risks may propagate across business sectors (which may or may not be HEIs) and through the economy. Given the complexity of value chain, banks focused on sectors that exhibit substantial interconnections and potential impacts. Some banks estimated sector-specific pass-through rates to measure the spill-over impact, while others applied adjustments based on expert judgment or references from academic research.

Estimate impact on obligors' financials

After identifying the transmission channels, the participating banks typically analysed the potential impacts of transition on the financial performance of obligors in the affected sectors. They developed models to project changes in the key financial indicators for these obligors, taking into account the scenario assumptions, transmission channels and company-specific information, such as business profiles, transition plans, emission data and existing financial performance. The common key financial indicators considered by the participating banks include:

(i) Revenue: It could be affected by product (or service) demand and pricing power. Companies that fall behind in transition may lose market share, resulting in a decline in product demand. Pricing power may depend on whether the companies can pass on the transition costs to their customers.

(ii) Cost of goods sold: Transition policies may affect the prices of raw materials and energy, thereby affecting the cost of goods sold.

(iii) Capital expenditure: Investments in low-emission technologies or energy efficiency improvements in production processes would increase a company's capital expenditure. Transition policies may accelerate the depreciation of certain assets (e.g. coal-fired power plants), which also leads to higher capital expenditure.

(iv) *Financing costs:* Companies may need to borrow additional funds to support their investments for transforming into a low-emission business model. As a result, the leverage and hence credit quality of a company may be affected by the nature of its business and transition strategies, thereby impacting its financing costs.

The participating banks used the projected financial indicators as inputs for estimating their obligors' financial positions along the transition pathways. Specifically, the banks conducted detailed counterparty-level assessments for at least the top 30% of their aggregate exposures to each of the HEIs. The impacts for the remaining exposures were extrapolated from these top exposures within the same sector, with conservative adjustments (e.g. multipliers) to account for the potential idiosyncratic nature of these exposures.

Assess financial implications for banks

The next step is to assess how the projected financial performance of corporates would influence their PD and LGD (or other credit risk metrics), and thus the credit risk of the participating banks. This process was relatively straightforward for most of the participating banks by leveraging their existing stress testing models.

In addition to the impact on credit risk, the participating banks also evaluated the implications of transition policies for their traded risk portfolios, which mainly consisted of investments in bonds and equities. The valuation of these securities are closely tied to the financial performance of the issuing companies. Changes in a company's financial performance can significantly affect market (investors) perceptions and consequently the prices of its bonds or shares. The participating banks estimated the changes in market values of bonds and equities based on fundamental analysis, asset value theory and correlation studies of their traded risk exposures by relating the HEI exposures to relevant market indices.

Other considerations

(i) Portfolio mix adjustment to reflect climate commitments: The participating banks were required to adopt a static balance sheet assumption under both the short-term and long-term scenarios in order to identify the potential vulnerabilities based on their actual financial positions and current business strategies. Nevertheless, they might consider adjusting their portfolio mix in their assessments under two of the long-term transition scenarios (i.e. the Below 2°C and Delayed Transition scenarios) if they had already established clear climate strategies with measurable commitments or goals on transition. Only a minority of the participating banks adjusted their portfolio mix to reflect their established climate commitments in the exercise (see Box 5).

Box 5: Portfolio mix adjustment to reflect banks' climate commitments

One participating bank has established clear policy regarding financial services for coal-fired power generation (CFPG) companies, pledging to provide financial services to these companies only if they have a strategy to phase out CFPG plants by 2040. This bank was also committed to ending the existing customer relationships with CFPG companies by 2040 for those not having a clear transition plan.

To integrate its climate commitments into the CRST assessment, this bank evaluated the credibility of its customers' transition plans. For customers deemed unable to transition away from CFPG plants, the bank assumed its relationship with these customers would be terminated in 2040. Conversely, for customers with viable transition strategies, their loan exposures would remain in the portfolio for assessment.

(ii) Transition risk impact on mortgage loans: While most participating banks' transition risk assessment focused on their corporate loan portfolios, one participating bank extended its assessment to mortgage loans. This bank assumed that all buildings must comply with new standards aimed at minimising carbon footprint or improving energy efficiency under the Below 2°C scenario. Compliance with these standards would involve adopting renewable energy sources and using eco-friendly materials. As a result, property owners were assumed to face increased costs for building maintenance or reconstructions, potentially impacting their ability to repay mortgage loans.

6. CAPABILITY BUILDING OF BANKS

6.1 Enhanced capabilities

The pilot CRST in 2021 revealed some gaps in banks' assessment of climate risks, particularly those concerning data availability and assessment methodologies. In response, banks have invested substantial efforts in collecting more granular data, investigating the transmission channels of climate risks and enhancing their assessment methodologies.

In addition to internal development and research, many banks acquired the necessary skills and knowledge by engaging external consultants and data vendors with expertise and resources in this area. To further facilitate the capability building of banks, the HKMA has launched several initiatives to support them in assessing climate risks (see Box 6). The banks participating in CRST 2.0 have demonstrated their strengthened capabilities for measuring climate risks, of which some have been discussed in Chapter 5 of this report.

(i) Data collection: Many banks have taken a range of actions to address the data gaps identified in the pilot exercise. Specifically, they have enhanced their Know-Your-Customer (KYC) procedures by collecting additional climate-related information to better assess their customers' transitions. The data collection process can be labour-intensive. One participating bank is developing tools using artificial intelligence to reduce this burden (see Annex B). In addition, the participating banks have been paying special attention to recent climate events and the associated impacts. Some of them conducted on-site visits to the severely affected locations after extreme climate events in order to evaluate their impacts on the collateral pledged by customers.

(ii) Scope of assessment: In the pilot exercise, participating banks focused on assessing the physical risk of property-related lending and the transition risk of the specified high-emitting industries. In CRST 2.0, participating banks expanded the scope of assessment to cover their entire balance sheets as well as off-balance sheet exposures. For instance, the participating banks also evaluated the impact of physical risk on non-property related lending, particularly their exposures to obligors whose repayment ability would be severely affected by extreme climate events. The impact of transition risk on the non-HEIs were also assessed. The increased coverage has contributed to a more comprehensive assessment of climate risks.

(iii) Assessment methodologies: For CRST 2.0, most participating banks adopted scientific approaches and conducted more granular assessments based on credible literature and academic research. This, as compared to relying heavily on judgemental assumptions, has enhanced the reliability of their assessment results (see Annex C for the reference materials commonly considered by banks). Another major advancement is that many participating banks used sophisticated climate models to simulate different climate hazard pathways to support their assessment, with some of these models even capable of estimating the combined impact of multiple climate hazards.

(iv) <u>Model risk governance:</u> The participating banks have strengthened their model risk governance framework for ascertaining the reliability and robustness of the climate risk assessment models employed. Many banks have undertaken thorough reviews of the models developed by third-party vendors by, for instance, benchmarking their results against credible research and studies. In addition, the banks also conducted sensitivity analyses to evaluate the impact of changes in the major model assumptions and parameters on the model outputs. These measures have improved the transparency and auditability of the assessment process, fostering greater confidence in the model-based climate risk estimates.

(v) <u>Cross-entities collaboration:</u> Climate scenario analysis is increasingly recognised as an important tool for managing climate risks, and regulators in various jurisdictions have already conducted or are planning to launch their industry-wide CRSTs. Many international banking groups therefore have CRST experience across different regions, allowing knowledge sharing and skill transfer across member entities within the group. This collaboration has steepened the learning curve and enhanced the overall capability in measuring climate risks for the whole banking groups.

Box 6: HKMA's initiatives to support banks in conducting climate risk assessments

1. Green and sustainable finance (GSF) data portal

In 2022, the Cross-Agency Steering Group (CASG), co-chaired by the HKMA and the Securities and Futures Commission, launched the GSF data portal to support the financial sector in locating data sources for climate risk management and other GSF-related analysis and research. The portal contains various Government data sources relevant to the assessment of physical risks in Hong Kong, including historical data on catastrophe damages, district level micro-climate conditions (such as tropical cyclones, flooding, landslides and storm surges) as well as geographic data and a coordinate transformation tool.

2. Greenhouse gas (GHG) emissions calculation and estimation tools

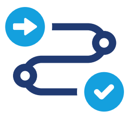
The CASG has partnered with the Hong Kong University of Science and Technology to develop GHG emissions calculation and estimation tools (the Tools). The Tools, launched in 2024, include a calculation utility for determining GHG emissions based on actual activity levels and an estimation tool for gauging the GHG emissions of their investees or borrowers where data of the underlying companies are limited. The Tools are aimed to assist non-listed companies in completing the Climate and Environment Risk Questionnaire developed by CASG (the Questionnaire), thereby improving the availability of emission data to the financial sector.

3. Physical risk assessment platform

In 2024, the HKMA, in collaboration with KPMG Advisory (Hong Kong) Limited and XDI Pty Ltd, developed the physical risk assessment platform (the Platform) with the aim of providing an exploratory and capacity building tool to facilitate banks' physical risk assessments. The Platform comprises (i) an analytical tool which allows users to assess the potential impact of physical risks on residential and commercial buildings in Hong Kong under different climate scenarios and (ii) a database of more than 40 public data or data sources related to physical risk.

6.2 Areas for further work

The participating banks have made significant progress in strengthening their climate risk measurement capabilities. Notwithstanding this, the HKMA has identified the key areas below from CRST 2.0 where banks can focus their efforts to further enhance their climate risk assessment framework.

Data collection 	One of the fundamental elements of effective climate risk assessment is robust data collection. While banks have made substantial efforts in gathering climate-related data, there is still potential for further enhancements to increase the reliability, comprehensiveness and granularity of the data used for climate risk assessment.
Backtesting 	Backtesting is as a useful tool in evaluating the reliability and robustness of climate risk assessment models. By analysing the actual impact of recent extreme climate events against model estimates, for instance, banks can gain useful insights into the performance of their models for further enhancements where necessary.
Second order impact 	Assessment of second order impact is complicated but essential for a comprehensive climate risk assessment. Developing a robust framework to better capture the second order impact will assist banks in analysing the cascading effects that may not be immediately apparent.

7. WAY FORWARD

Against the backdrop of the growing threat of climate change, continuous enhancement in climate risk assessment capabilities is essential for the robust development of the banking sector.

1. Supervisory guidance

The HKMA will continue to provide supervisory guidance and feedback to the industry, supporting banks' efforts in climate-related risk management under the Sustainable Finance Action Agenda.

2. Continued engagement with the industry

The HKMA recognises the importance of ongoing engagement with the industry. In particular, climate risk stress testing is still a relatively new risk management tool. The evolving landscape of climate risks necessitates continuous enhancements to keep the industry as well as the HKMA's understanding up-to-date and relevant. Ongoing engagement, which may include workshops or forums, can facilitate knowledge sharing and help support banks in navigating the complexities of assessing and managing climate risks effectively.

3. Optimising the integration of climate risks into regular supervisory stress test

The introduction of the short-term scenario in CRST 2.0 lays the foundation for integrating climate risks into the HKMA's SDST framework. Leveraging the experience of the exercise, a major short-term target of HKMA is to optimise the integration so that banks can assess climate-related shocks in their regular stress tests, thereby minimising the duplications for them to conduct CRST separately. This initiative will also support banks to incorporate climate risk considerations in their internal risk management process, such as internal capital adequacy assessment process and strategic planning, thereby fulfilling the relevant supervisory expectations for climate risk management.

ANNEX A – LIST OF PARTICIPATING BANKS

Agricultural Bank of China Limited

Australia and New Zealand Banking Group Limited

Bank of America, National Association

Bank of China (Hong Kong) Limited

Bank of Communications (Hong Kong) Limited

Bank of Communications Co., Ltd.

The Bank of East Asia, Limited

BNP Paribas

China CITIC Bank International Limited

China Construction Bank (Asia) Corporation Limited

China Construction Bank Corporation

China Development Bank

China Everbright Bank Co. Ltd

China Merchants Bank Co. Ltd

China Minsheng Banking Corp,. Ltd

Chiyu Banking Corporation Limited

Chong Hing Bank Limited

Citibank (Hong Kong) Limited

Citibank, N.A.

CMB Wing Lung Bank Limited

Credit Agricole Corporate and Investment Bank

Credit Industriel Et Commercial

Dah Sing Bank, Limited

DBS Bank (Hong Kong) Limited

DBS Bank Ltd.

First Abu Dhabi Bank PJSC

Fubon Bank (Hong Kong) Limited

Hang Seng Bank, Limited

The Hongkong and Shanghai Banking Corporation Limited

Industrial and Commercial Bank of China (Asia) Limited

Industrial and Commercial Bank of China Limited

Industrial Bank Co., Ltd

JP Morgan Chase Bank, National Association

Mizuho Bank Ltd.

Morgan Stanley Bank Asia Limited

MUFG Bank, Ltd

Nanyang Commercial Bank, Limited

NATIXIS

OCBC Bank (Hong Kong) Limited

Public Bank (Hong Kong) Limited

Shanghai Commercial Bank Limited

Shanghai Pudong Development Bank Co., Ltd.

Societe Generale

Standard Chartered Bank (Hong Kong) Limited

Sumitomo Mitsui Banking Corporation

United Overseas Bank Ltd

ANNEX B – CASE STUDY: USING ARTIFICAL INTELLIGENCE TO COLLECT CLIMATE-RELATED DATA

High-quality data are essential for modelling climate risks, but the information is often scattered across various sources such as disclosures and reports. This makes extraction and compilation labour-intensive and time-consuming. The emergence of artificial intelligence presents a viable solution to streamline this process.

One participating bank is developing tools adopting artificial intelligence technologies, including machine learning and deep learning, to enhance the collection of climate-related data, thereby improving decision-making processes across the group. Specifically, the tools assist staff in sourcing data from data providers and public sustainability reports of corporations in various formats, as well as completing a pre-set questionnaire related to corporate transitions. The tools can not only streamline the data collection process but also reduce the likelihood of human errors. In essence, the artificial intelligence tools comprise the following modules:

<u>Data extraction</u>

The process begins with extracting tables and texts from data providers and corporates' sustainability reports. Table detection and algorithm are deployed for accurate extraction. In addition, optical character recognition is used to convert different types of documents (e.g. scanned paper documents and images captured by a digital camera) into a machine-readable format.

<u>Retriever</u>

A module is developed to retrieve the most relevant contexts based on user requirements. This strategic approach allows users to focus on the most important information to improve the efficiency and accuracy of the subsequent question and answering module.

<u>Question and answering (Q&A)</u>

A set of prompts are constructed based on the questions in a pre-set questionnaire and the retrieved information for guiding the Q&A module in generating responses. The Q&A module processes prompts and generates answers to the questionnaire.

<u>Questionnaire Pre-fill</u>

The responses generated by the Q&A module are utilised to prefill the questionnaire.

As artificial intelligence technology is still evolving, it is crucial to implement sufficient control and governance. Artificial intelligence models often operate with black-box approach, suffering a degree of opacity and randomness, and posing challenges in understanding their reasoning and decision-making processes. Hence, it is essential for banks to maintain adequate control and oversight over artificial intelligence models to ensure responsible and effective implementation. For example, sample checking of the generated results can verify the accuracy of the data extracted by the artificial intelligence models; exploring the usage of various prompt engineering techniques (e.g. Chain-of-Thought Prompting) when using the Q&A module can facilitate understanding and improving the model reasoning steps; and expanding the framework of Explainable Artificial Intelligence (XAI) can enhance the transparency and users' ability to interpret the black-box models.

ANNEX C – LIST OF USEFUL REFERENCES CONSIDERED BY PARTICIPATING BANKS

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