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TECHNICAL NOTE ON CLIMATE RISKS ANALYSIS

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July 28, 2025

TECHNICAL NOTE

CLIMATE RISK ANALYSIS

Prepared By
Monetary and Capital Markets Department

This Technical Note was prepared by IMF staff in the context of the Financial Sector Assessment Program in Country. It contains technical analysis and detailed information underpinning the FSAP's findings and recommendations. Further information on the FSAP can be found at
http://www.imf.org/external/np/fsap/fssa.aspx

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Glossary

AMF	Autorité des marchés financiers (Québec)
BOC	Bank of Canada
BUI	Buildup Index
CAD	Canadian Dollars
CDR	Cash Debt Ratio
CP	Current Policies
CMHC	Canada Mortgage and Housing Corporation
CSD	Census Subdivision
DT	Delayed Transition
DTI	Deposit Taking Institution
D-SIB	Domestic Systemically Important Bank
D-SIFI	Domestic Systemically Important Financial Institution
EBIT	Earnings Before Interest and Taxes
EBITR	Earnings Before Interest and Taxes Total Asset Ratio
ECCC	Environment and Climate Change Canada
FA	Federal Authorities
FSA	Forward Sortation Area
FSAP	Financial Sector Assessment Program
FSL	Fire Season Length
FWI	Fire Weather Index
GDP	Gross Domestic Product
GHG	Green House Gas
HELOC	Home Equity Line of Credit
ICE	Intercontinental Exchange
ICR	Interest Coverage Ratio
km	kilometer
LGD	Loss Given Default
LEV	Leverage
LTV	Loan-to-Value
NRCan	Natural Resources Canada
OSFI	Office of the Superintendent of Financial Institutions
NFC	Non-Financial Corporate
PA	Provincial Authorities
PD	Probability of Default
P&C	Property and Casualty
P&L	Profit and Loss
PiT	Point-in-Time
PP	Percentage Points
PS	Public Safety Canada
RCP	Representative Concentration Pathway
RESL	Residential Real Estate Secured Lending

SCSE	Standardized Climate Scenario Exercise
T0	Time 0
TTC	Through-The-Cycle
WUI	Wildland-Urban Interface
ZEV	Zero Emissions Vehicle

EXECUTIVE SUMMARY[1]

The financial sector in Canada is exposed to both physical and transition climate risks. Floods and wildfires are prominent hazards, and climate change could increase their intensity. As a major fossil fuel producer, Canada is also exposed to transition risks, the 10th largest global emitter, and has committed to reduce emissions by 40–45 percent by 2030 relative to 2005.

The Financial Sector Assessment Program (FSAP) reviewed the authorities' framework for climate risk analysis. The authorities' climate risk analyses adopt state-of-the-art methodologies and leverage granular data from both public and private sources. The Office of the Superintendent of Financial Institutions (OSFI) and the Autorité des marchés financiers (AMF), with valuable feedback from Bank of Canada (BOC), are currently conducting their first Standardized Climate Scenario Exercise (SCSE), which is a comprehensive climate risk stress test covering most Canadian financial institutions. [2] The SCSE covers both transition risks and a physical risk exposure assessment for floods and wildfires. This exercise significantly expanded the coverage from the pilot analysis conducted by OSFI and BOC in 2020 (Chen et al. 2022). Additionally, authorities have conducted top-down analyses, such as a flood risk stress testing on residential lending portfolios (Johnston et al. 2023), and an analysis of the systemic implications of transition risk including both direct and indirect effects on the Canadian financial system (Bruneau et al. 2023).

Canadian regulators are working on advancing climate risk management in financial institutions. The SCSE is particularly useful for building capacity for participating institutions. Going forward the authorities' role will be reduced and instead there will be more emphasis on the capacities developed within financial institutions.[3] In terms of the authorities' own climate risk analysis, the FSAP recommends moving away from private data vendors towards data sharing and additional collaboration with climate experts in Canada.[4] In the design and execution of SCSE, OSFI closely collaborated with AMF. However, efficiency of such collaborations could be improved through more advanced data standardization and sharing between provincial and federal authorities (FA) (both financial and climate).

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[1] This Technical Note has been prepared by Caterina Lepore, Financial Sector Expert, and Tumer Kapan, Senior Financial Sector Expert, at the Monetary and Capital Markets Department of the IMF, and Hugo Rojas-Romagosa, Senior Economist at the Research Department of the IMF. This note is based on the work of an IMF FSAP mission to Canada during October 21-November 4, 2024, and February 10–24, 2025.

[2] https://www.osfi-bsif.gc.ca/en/data-forms/reporting-returns/standardized-climate-scenario-exercise, https://lautorite.qc.ca/en/professionals/insurers/standardized-climate-scenario-exercise-scse.

[3] OSFI has already started collecting standardized climate-related emissions and exposure data, directly from financial institutions, and has issued guidelines establishing OSFI's expectations related to the financial institutions' management of climate-related risks. See https://www.osfi-bsif.gc.ca/en/data-forms/reporting-returns/filing-financial-returns/financial-reporting-instructions/business-specifications-climate-related-risk-returns-deposit-taking-institutions-dtis; https://www.osfi-bsif.gc.ca/en/guidance/guidance-library/climate-risk-management.

[4] In particular, data sharing and collaborations with the authorities that produce climate data (e.g., Public Safety Canada (PS), Natural Resources Canada (NRCan) and ECCC) would facilitate the further development of climate risk analysis by financial regulators.

The FSAP also performed an independent analysis of key physical and transition risks for large deposit takers. The focus of these analyses is on developing methodologies and enhancing awareness of climate risks and associated challenges in climate risk assessment. The climate risk analysis covered the six domestic systemically important banks (D-SIBs) and Québec's cooperative credit institution which is designated as a domestic important financial institution (D-SIFI). These seven systemic deposit-taking institutions (DTIs) hold over 90 percent of overall DTI assets.[5] The physical risk analysis investigated wildfire risks to residential properties which serve as collateral for mortgages using a micro-approach. This was an exploratory exercise, given it was the first time a wildfire risk analysis was performed as part of an FSAP and given large uncertainties and data limitations. The transition risk analysis identified potential pressure points from the transition to a low-carbon economy, focusing on the nonfinancial corporate (NFC) sector.

At the DTI sector level, the pool of residential real estate mortgages is geographically diversified across Canada, but exposed to notable climate-related wildfire risks. A significant portion of loans is located in areas with very high or extreme fire-weather, and this portion is expected to increase with climate change under both medium and high-emissions scenarios already by mid-century.

The analysis suggests that the losses of systemic DTIs could be considerable under the most severe scenarios. An innovative wildfire risk analysis estimated potential losses for the seven systemic DTIs, conditional on default of borrowers, for residential real estate lending in areas with extreme fire-weather and where there are wildland fuels. The analysis accounted for the role of both mortgage and property and casualty (P&C) insurance. The increase in DTIs' loss given defaults (LGDs) would vary significantly by province and scenario. LGDs would increase significantly more under the high emission scenario than the medium emission scenario relative to historical climate; similarly, LGDs of loans in some provinces would increase substantially more than those in other affected provinces. Further, loans with high Loan-to-Value (LTV) are more sensitive to wildfire-driven losses, although these represent a small portion of mortgages.

Results are sensitive to several parameters, such as the damage function and the rate of pass-through of damages to DTIs. For instance, increasing the pass-through rate of wildfire damages to DTIs leads to substantially larger LGDs. Similarly, results are also sensitive to the damage function adopted. If all houses experiencing a fire were to be destroyed completely, DTIs' losses would be significantly higher.

The transition risk analysis finds heterogeneous results by sectors, with notable impacts for heavy emitters. Under the transition scenarios, NFCs' credit risk would generally increase modestly but with significant variations across sectors. Notable impacts are observed for the oil and gas sector. The electricity non-renewable sector also stands out as experiencing the largest relative Probability of Default (PD) increase under the two transition scenarios relative to baseline in 2040.

[5] In the rest of the note the seven institutions covered in the analysis are referred to as the "seven systemic DTIs".

While a delayed transition (DT) entails lower costs in earlier years, from 2040 on losses exceed that of the Net Zero 2050 scenario. The adverse impact is larger under Net Zero 2050 than under DT for most of the simulation period; however, by 2040 DTIs' credit losses under DT begin to exceed the ones under Net Zero.[6] This reversal in magnitude of losses is due to the rapid transition under the DT scenario starting from 2030s. The credit losses are estimated to increase between 3.8–7.1 percent under the Net Zero 2050 and DT scenarios relative to current policies (CP) by 2040. The cumulative losses are still greater under the Net Zero 2050 scenario; however, this is driven by the fact that the simulation period ends in 2040, just as the adverse effects of the DT on the NFC sector begin to exceed those of the Net Zero 2050 scenario.

Results from these analyses, while indicative, should be interpreted with caution given various data and modeling limitations. The wildfire risk exposure analysis might underestimate concentration of individual banks' exposures, which are not identifiable in the FSAP dataset. Further, the wildfire risk analysis relies on a simplified methodology due to data and methodological constraints, such as lack of Canada-wide wildfire hazard data and damage function. More broadly, the physical risk analysis only covers one hazard and does not account for compounding effects, hence it is likely underestimating physical risks. The transition risk assessment only covers NFC loans in excess of 10 Canadian dollars (CAD) million due to data limitations, leaving out smaller firms, which are, potentially, more vulnerable to financial shocks. Further, the transition scenario ends in 2040 when the impact of a DT starts to become more impactful. Finally, both analyses focus on a specific credit risk channel and only capture direct impacts, ignoring indirect and systemic effects, hence potentially underestimating overall climate risks facing the Canadian banking and deposit-taking sector.

[6] Results calculate annual expected losses and do not follow the IFRS 9 methodology.

Table 1. Canada: Recommendations on Climate Risk Analysis			
	Recommendations	**Agency**	**Timing[1]**
1.	Strengthen data sharing and collaboration with natural hazard and climate experts.	OSFI, BOC, AMF jointly with relevant climate agencies[2]	MT
2.	Establish standardized public climate data and risk frameworks across provinces (including damage functions).	FA, PA	MT
3.	Expand physical risk assessment (geographical areas, hazards damages, scenarios, return periods).	OSFI, BOC, AMF	MT
4.	Remove barriers for exchange of confidential information between federal and provincial authorities (PA).	OSFI, AMF, FA, PA	ST
5.	Enhance data standardization and cooperation between provincial and FA.	OSFI, AMF, FA, PA	MT
6.	Strengthen the supervision of the adequacy of property insurance protection on the collateral held by banks and insurance companies.	OSFI, AMF	MT
7.	Move away from private data vendors towards public or internal data (when possible).	OSFI, AMF	MT

[1] I —Immediate (within 1 year), ST—Short term (within 1–2 years), MT—Medium term (within 3–5 years)

[2] PS, NRCAN, and ECCC. See footnote 4.

PHYSICAL RISK ANALYSIS

A. Physical Risks in Canada

1. **Canada is exposed to a broad range of physical risks given its vast geography**. Atlantic Canada faces hurricanes, rising sea levels, and coastal erosion; Québec deals with extreme cold, ice storms, flooding, and wildfires; Ontario contends with extreme heat, flooding, and tornadoes; the Prairies are vulnerable to drought, flooding, hailstorms, and wildfires; British Columbia experiences wildfires, flooding, landslides, and rising sea levels; Northern Canada faces permafrost thawing, loss of sea ice, and wildfires; and the Arctic region is rapidly warming, leading to sea ice loss, permafrost thawing, and coastal erosion.

2. **Natural disasters can have macroeconomic consequences.** This is demonstrated by a series of recent studies from Bank of Canada. Dahlhaus et al. (2025) finds that disasters increase volatility in Gross Domestic Product (GDP), with a negative cumulative impact of up to -1.5 percent over a maximum of 18 months in the absence of federal aid. Duprey and Fernandes (2025) finds that natural disasters can significantly increase the volatility of inflation across Canada in the short term and significantly impact provincial inflation over the long term due to shelter costs. Duprey et al. (2024) finds that natural disasters can negatively affect workers, mainly through changes in hours worked and wage growth.

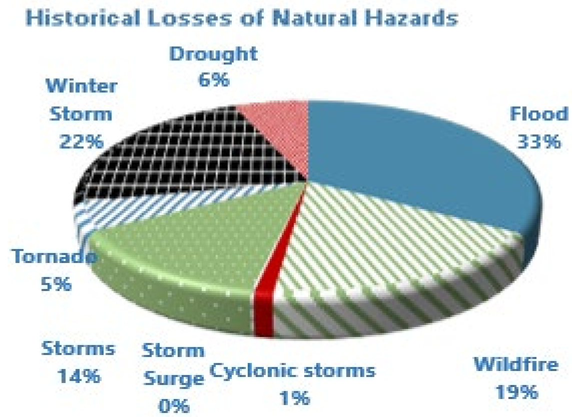
3. **Floods and wildfires are prominent hazards.** Historically floods and wildfires are among the most frequent and costliest of natural hazards in Canada (Figure 1). The wildfire in Fort McMurray (northern Alberta) in 2016 has been the most expensive natural disaster in the history of Canada, with an estimated 9.9 CAD billions worth of insured and uninsured damages. The estimated impact on GDP in the second quarter of 2016 is -0.4 percent (Statistics Canada).

4. **Climate change can further exacerbate wildfires.** Numerous studies have explored how climate change affects the severity of fire weather. Recent research from the Canadian Centre for Climate Services (Environment and Climate Change Canada (ECCC)) indicates "substantial, robust increases in the frequency and severity of high fire weather conditions as well as a lengthening of the fire season across most of Canada by the end of the twenty-first century" under the Representative concentration pathway (RCP) 4.5 and RCP 8.5 (Van Vliet et al. 2024).[7]

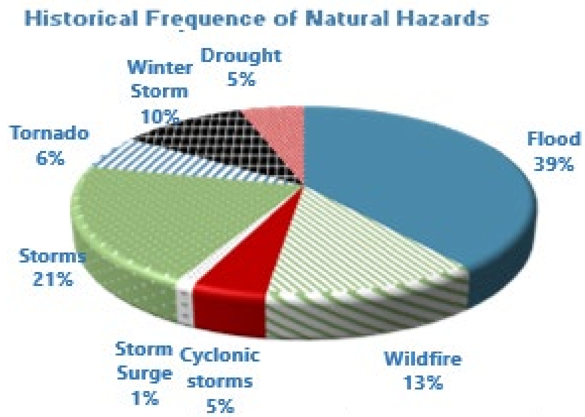
[7] In RCP-based scenarios, RCPy, the number 'y' refers to the level of radiative forcing (in watts per square meter) resulting from the scenario in the year 2100. RCP 4.5 and 8.5 represent an intermediate and very high Green House Gas (GHG) emissions scenarios respectively (IPCC 2023).

Figure 1. Canada: Physical Risks

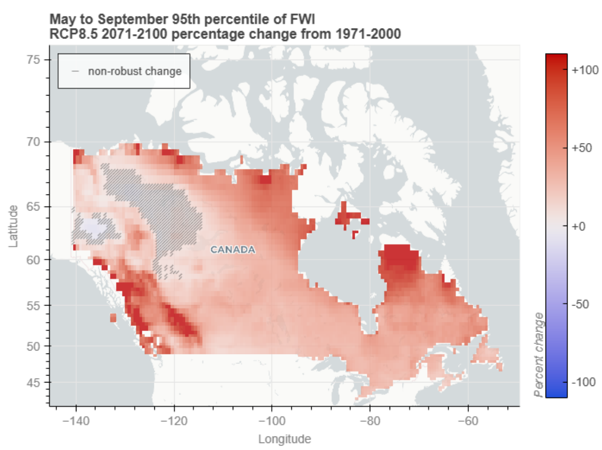
Floods and wildfires are among the costliest and…



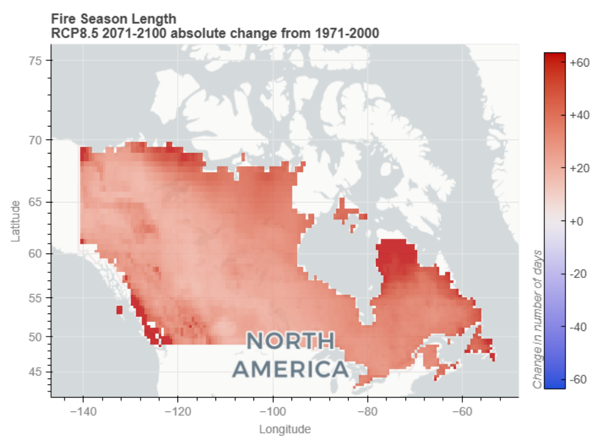
…most frequent natural hazards in Canada.



Climate change can further exacerbate natural hazards. By end century, under RCP 8.5, wildfire intensity (as measured by the Fire Weather Index (FWI)) and…



…the length of fire season are projected to increase substantially relative to 1971–2000 across most of Canada.



Sources: Public Safety Canada (The Canadian Disaster Database), ECCC (ClimateData.ca).

Note: The top two charts represent the share by natural hazard of total historical losses (left) and number of occurrence (right) from 1900 to present day in Canada. See https://www.publicsafety.gc.ca/cnt/rsrcs/cndn-dsstr-dtbs/index-en.aspx for more information.

B. Authorities' Physical Risk Analysis

5. **The authorities have conducted detailed analysis on floods risk.** The OSFI and Bank of Canada (BOC) performed a top-down flood risk stress testing on banks' residential lending portfolios (Johnston et al. 2023). The exercise used damages estimations provided by Public Safety Canada (PS). PS estimated damages from floods using flood hazard data from private data vendors. PS estimated the average expected flood-related loss for residential real estate to be CAD 2.97 billion per year. PS estimated this loss to increase by 6.7 percent and 11.9 percent under RCP 4.5 and RCP 8.5 scenarios by the year 2100 relative to the baseline. BOC then mapped these damages to

granular data on banks' residential loans using postal code information along with information on mortgage and P&C insurance.

6. The authorities' results showed modest impacts on banks' mortgage portfolio, but borrowers with LTV ratio above 80 percent were found to be more sensitive to floods. The authorities examined the financial impact of both annual average floods (taken as a baseline) and 1-in-100-year flood event (taken as a severe event) by the year 2100 under RCP 4.5 and RCP 8.5. They found that damages from these floods have modest impacts on financial institutions' LGDs for their residential real estate secured lending (RESL) portfolio. They attributed these modest impacts to homeowner equity and recent rise in house prices in Canada. The study included significant limitations that understate the risks, such as the authorities' access to granular location data and the use of a simplified LGD formula.

7. OSFI and AMF are currently running their first SCSE, which covers floods and wildfires. SCSE combines top-down elements, such as shared scenarios and risk factors, with a bottom-up approach requiring institutions to use their own exposure data, classification methods, and non-climate-related modeling frameworks to determine actual impacts. The objectives of the exercise are to raise awareness, build capacity, and execute a standardized quantitative assessment across the participating institutions. This is a comprehensive climate risk stress test covering most Canadian financial institutions. SCSE includes an exposure assessment for both floods and wildfire risks. Floods data are sourced from a private data vendor, given the lack of public nationwide forward-looking flood data from the relevant authorities in Canada. Wildfires data are publicly available from the data published and maintained by ECCC.[8] Participating institutions are asked to map hazards' data to their geocoded exposures (mortgages, home equity line of credit (HELOCs) non-mortgage loans and reverse mortgages secured by residential property and other) for some selected geographical regions (urban areas for floods and rural areas for wildfires).

8. The authorities' physical risk work is foundational. The flood risk stress testing was a pilot exercise that used a micro-approach leveraging loan level data and flood maps from PS. However, the study was constrained by privacy considerations, which limited the full use of address level data. The SCSE helped build capacity for participating institutions, for example in terms of geocoding their exposures. However, it was not a full physical risk assessment (e.g. it did not estimate damages from wildfires). The current physical risk module of SCSE is restricted in scope: it only includes an exposures assessment, and it is confined to selected geographical regions. This could result in overlooking some important risk areas, in particular for wildfires. It is also advisable to move away from private data vendors towards data sharing and collaboration with climate experts and authorities in Canada when possible and, especially, as more data becomes available in the medium term.[9] However, this is challenging at the moment due to data gaps and lack of a common climate risk assessment framework in Canada.

[8] https://climatedata.ca/fire-weather/

[9] For example, Public Safety is leading development of an open-source flood hazard data, expected to be complete in a few years.

9. Collaboration between provincial and FA could be enhanced. SCSE is a good example of collaboration between OSFI and AMF. However, there are still impediments to sharing information and data standardization. For example, RESL dataset, which collects loan level data on residential real estate secured lending, contains information on the location of the residential real estate at different resolutions: AMF data contains location information at the forward sortation area (FSA) level while OSFI location data is reported at the postcode level.

10. Given that the authorities have already conducted extensive work on floods risk, the FSAP team, in agreement with the Canadian Authorities, decided to focus on wildfire risks. The physical risk analysis performed by the FSAP team seeks to investigate banks' financial stability risks from wildfires under current and future climate conditions. As of the time of the FSAP, this analysis was among the first studies to perform a wildfire risk analysis for the DTI sector. Hence, the FSAP team considered this as an opportunity to add more value to the authorities' climate risk analysis and to continue building methodologies for future FSAPs. The focus of this exploratory analysis is on developing methodologies and enhancing awareness of climate risks and associated challenges in climate risk assessment. The analysis focused specifically on the potential risks from wildfires' impacts on residential properties in Canada which serve as a collateral for DTIs' mortgages.

C. Financial Sector Assessment Program Wildfire Exposure and Risk Analysis

Background

11. There are a variety of stakeholders involved in analyzing and managing wildfire risk in Canada. Responsibility for wildland fire management in Canada rests primarily with the provinces and territories. The federal government plays a key role in wildfire management by supporting provinces and territories with science, technology, emergency management (Public Safety Canada), and managing fires on federal lands (Parks Canada, Department of National Defense). NRCan is the federal government's primary source of wildland fire technical and scientific expertise, providing leadership and guidance that is helping to shape national approaches to prevention, mitigation and response.[10]

12. The Government of Canada has many programs and initiatives that look to support action on wildfires. For instance, the Canadian Forest Service is working on a national wildfire risk assessment in partnership with ECCC Public Safety Canada and the National Research Council of Canada to quantify wildfire risk in Canada. This project, currently under development, will leverage expertise across numerous departments to fill knowledge gaps and perform a 'first of its kind'

[10] NRCan conducts cutting edge science, provides critical situational information and decision-supports to assist in on-the-ground response and planning (such as monitoring, situational reporting, and modeling) and maintains the Canadian Wildland Fire Information System (CWFIS). The Department also manages international engagements and agreements for wildland fire cooperation and resource exchange.

wildfire impact assessment and quantification that will advance the federal government's capabilities in probabilistic hazard and risk assessments.[11]

13. There is currently no comprehensive publicly available nationwide hazard modeling in Canada. Canada's vast size and diverse landscape make it difficult to create national hazard models that accurately capture the unique risks faced by different regions. There is also little standardization and no unique definition in terms of specific fire hazard indicators. There is indeed a wealth of fire risk indicators and historical fire data publicly available (see Johnston et al. 2020), but no public data specifically on forward-looking fire likelihood (probability for a location to experience a wildland fire) and intensity (amount of energy produced by a fire) covering the entire country.[12,13] However, the Canadian Council of Forest Minister's Prevention and Mitigation Strategy is committed to developing and making accessible a wildland fire risk assessment framework and risk planning resources. The risk assessment framework is anticipated to be available to the public in the winter of 2025–26.

14. One commonly used fire indicator in Canada is the FWI. FWI is a numeric rating of fire intensity. It is used as a general index of fire danger throughout the forested areas of Canada. FWI consists of six components that account for the effects of fuel moisture and weather conditions on fire behavior. As reported by NRCan, the first three components are fuel moisture codes, which are numeric ratings of the moisture content of the forest floor and other dead organic matters. There is one fuel moisture code for each of three layers of fuel: litter and other fine fuels; loosely compacted organic layers of moderate depth; and deep, compact organic layers. The latter is called Drought Code as it represents a useful indicator of seasonal drought effects on forest fuels. The remaining three components are fire behavior indices, which represent the rate of fire spread, the fuel available for combustion (the so-called Buildup Index), and the frontal fire intensity. These three values rise as the fire danger increases. Calculation of the components is based on consecutive daily observations of temperature, relative humidity, wind speed, and 24-hour precipitation.[14]

15. ECCC has recently published forward-looking projections for FWI under different climate scenarios. The scenarios are RCP 2.6, RCP 4.5, and RCP 8.5. The data has a resolution of 50 kilometers (km) on a national scale. This information on fire weather can be combined with other information on fuel and ignition to develop a fuller picture of wildfire intensity changes.

[11] The first pass at this is published in Erni et al (2024) and is in the process of being updated. That study quantified risk based on the status of the forest conditions in 2017 and is therefore out of date in regions of the country that have experienced significant fires in the subsequent years.

[12] See Johnston et al. (2020) for a review of the wildfire risk research in Canada.

[13] While Canada-wide hazard data regarding burn probability and projections of increase in fire size and burn area exist, this data is not publicly available.

[14] https://cwfis.cfs.nrcan.gc.ca/background/summary/fwi

Data and Methodological Limitations

16. The FSAP adopted a simplified methodology for this analysis, given current data limitations and uncertainties. Annex I discusses what the ideal first-best methodology would be for the wildfire risk assessment in the absence of data or modelling constraints. Under both methodologies, the analysis focuses on direct impacts from wildfire, and indirect impacts are out of scope. The analysis considers wildfires in isolation, abstracting from the potential cascading effects of multiple natural hazards. Further, while the first-best approach accounts for how both climate system and socioeconomic processes could affect fire behavior, the simplified methodology used in this FSAP focuses on the impact of climate change on fire weather and abstract from other drivers of fire behavior (e.g. climate and socioeconomic changes impacting fuels and ignitions, as well as exposures and their vulnerability). The analysis relies on DTIs' data lacking highly granular geolocational information, which is kept static throughout the exercise.

17. The analysis is likely to underestimate physical risks. The analysis focuses on the combined mortgage portfolio of all seven systemic DTIs, due to data confidentiality reasons, hence individual DTIs' concentrations are not identified. The analysis also focuses on one specific channel of transmission of losses from wildfires to DTIs. Several other hazards and transmission channels are relevant and not included in this analysis. Further, the analysis is subject to large uncertainties given the lack of forward-looking data on fire likelihood and intensity as well as a damage function for Canada. The analysis represents an exploratory approach to analyzing wildfires given the available limited data.

Methodology

18. Physical risks arise as the interaction of three components: hazard, exposure and vulnerability (Figure 2). Changes in both the climate system and socioeconomic processes, including adaptation and mitigation, are drivers of hazards, exposure, and vulnerability.

Figure 2. Canada: Wildfire Risk Framework and Data

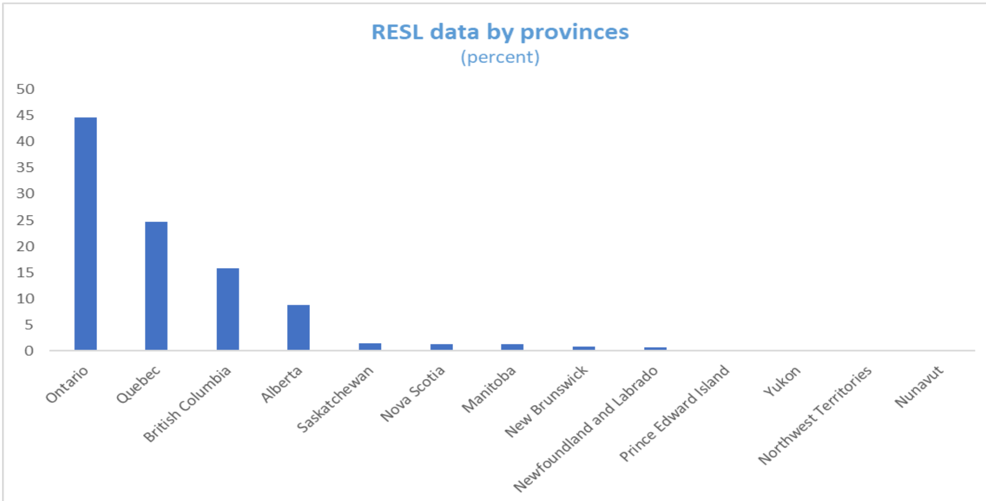
Source: ClimateData.ca.

19. The FSAP obtained a confidential anonymized loan-level dataset from the authorities on the seven systemic DTIs' mortgages collateralized by residential properties. The sample consisted of the six domestic systemically important banks (DSIBs) and Québec's cooperative credit institution which is designated as a domestic important financial institution (D-SIFI). The dataset contains several loan characteristics, including the value of the property (at the latest appraisal date) and its geographical location. OSFI provided RESL data for the 6 D-SIBs without an identifier for individual institutions. AMF provided RESL data for Québec's D-SIFI separately.[15] The RESL data cut-off date is September 2023. These exposures are kept fixed throughout the exercise. While the ideal residential real estate location information would be at the address level, the information received is at the census subdivision (CSD) level from OSFI and FSA level from AMF.[16] The dataset does not contain any information on the structure of the house or building codes. As a result, the analysis did not directly focus on individual buildings but on geographical areas where residential properties are located. The team processed the RESL loan-level dataset to create a property-level dataset, where loans (including HELOCs) on the same property are aggregated together. All property values have been updated to September 2023 using Teranet-National Bank House Price index. Loans with missing appraisal value, missing outstanding balance, non-positive outstanding balance, missing credit limit and zero outstanding balance were filtered out. The final dataset for the 6 D-SIBs spans 3,324 CSDs and 997 FSAs for Québec's D-SIFI for a total of 1,928 CAD Billions. The data spans all 10 provinces and 3 territories in Canada, with the largest loan amount observed in Ontario, followed by Québec and British Columbia (Figure 3).

[15] Due to the confidentiality of the data and the different geographical information, this note does not show separate data for Québec's D-SIFI in any geographical map, but only aggregated with the 6 D-SIBs in the other type of charts.

[16] Statistics Canada defines *Census subdivision* as "municipalities (as determined by provincial/territorial legislation) or areas treated as municipal equivalents for statistical purposes (e.g., Indian reserves, Indian settlements and unorganized territories). Municipal status is defined by laws in effect in each province and territory in Canada." A *FSA* is a way to designate a geographical unit based on the first three characters in a Canadian postal code. As of the 2021 Census there are 1,699 FSAs and 5,161 CSDs in Canada. See Annex II.

Figure 3. Canada: Distribution of Residential Real Estate Secured Lending Portfolio of 7 Systemic Deposit Taking Institutions Loan Amount Share by Province



Sources: RESL dataset and IMF Staff computation.

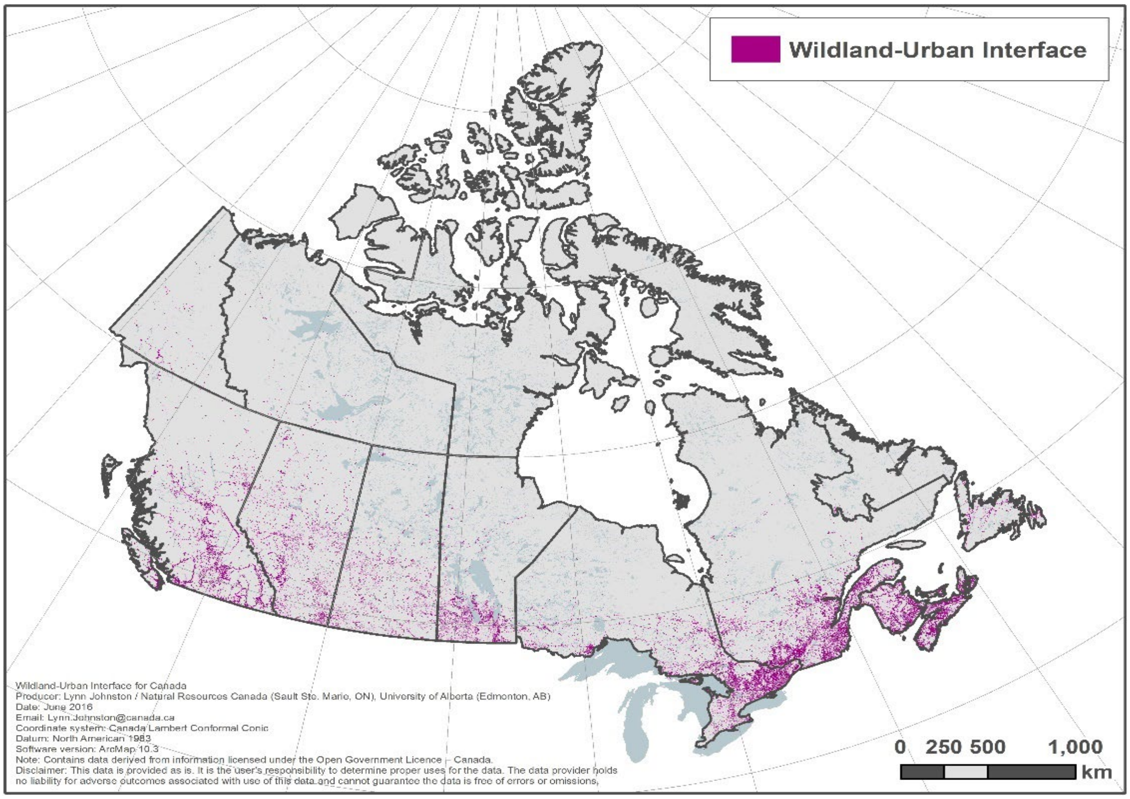
Note: The chart reports the share of total outstanding RESL loans for the seven systemic DTIs in each province.

20. The analysis leveraged the publicly available fire weather data. The focus is on two future time periods: 2041–2070 (mid-century) and 2071–2100 (end of the century) and two climate scenarios RCP 4.5 and 8.5 representing intermediate and high emissions scenarios, as well as an historical baseline (1971–2000). The team also received data from NRCan (Johnston and Flannigan (2018)) on the Wildland-Urban Interface (WUI), which was used for the wildfire risk analysis. WUI represents areas where fuels are close to potentially vulnerable human-built urban structures such as homes, public buildings or commercial structures (Figure 4).[17] The WUI data has been updated in 2019 to reflect updated data on structures. The data has a resolution of 30 meters on a national scale, which the team aggregated at a resolution of 10 km for tractability. Generally, wildfires occur more often and are more severe when there is: i) hot, dry, and windy weather, ii) flammable vegetation, and iii) more ignition sources (Figure 2).[18] The analysis accounts for the first two factors, hence ignoring ignition sources. Due to lack of available data on vulnerability the team adopted a reduced form approach as explained below.

[17] Specifically, selected structures as recorded in the CanVec+ dataset are: the majority of buildings and structures (including residential), but also places of interest, railway stations and structures, airport runways and man-made hydrographic entities.

[18] https://climatedata.ca/fire-weather/

Figure 4. Canada: Wildland-Urban Interface



Sources: Johnston and Flannigan (2018)

21. First, the FSAP analyzed DTIs' exposures to wildfire risks by contrasting their mortgages to wildfire weather data. The two datasets were matched using the nearest neighbor method for smaller CSDs and FSAs that do not entirely contain a 50km x 50km grid, and taking the average of the wildfire risk data of the grids contained in larger CSDs and FSAs.

22. The risk indicators utilized were measures of potential wildfire intensity as measured by the FWI, the Buildup Index (BUI) and Fire Season Length (FSL), under both historical and future climate scenarios (RCP 4.5 and RCP 8.5). For FWI and BUI, the metric adopted was the May to September ninety-fifth percentile, which is an indicator of the severity of high fire weather conditions. Each indicator was categorized in five buckets, from low to extreme, based on the same approach utilized by climatedata.ca.[19] The team also categorized banks' mortgages (percentage in the CSD or FSA over the total) in five buckets based on the quantiles of their overall distribution. As a result, DTIs' mortgages were categorized into 25 different buckets depending on both their loan amounts and fire risk indicator. This analysis helped the team understand if mortgages are

[19] Specifically, FWI≤5 is considered low, 5<FWI≤10 moderate, 10<FWI≤20 high, 20<FWI≤30 very high, FWI>30 extreme. Similarly, BUI≤20 is considered low, 20< BUI ≤40 moderate, 40< BUI ≤60 high, 60< BUI ≤90 very high, BUI >90 extreme. Finally, FSL≤100 is considered low, 100<FSL≤150 moderate, 150<FSL≤200 high, 200<FSL≤250 very high, FSL>300 extreme.

concentrated in areas with weather more conductive to fires, and whether this concentration will change under future climate.

23. Second, the FSAP estimated potential damages from wildfires in selected at-risk areas and the potential losses to DTIs conditional on defaults. Following Adrian et al. (2022) the team applied a micro approach, estimating wildfire damages in at-risk areas and then linking them to DTIs' loan level exposures.

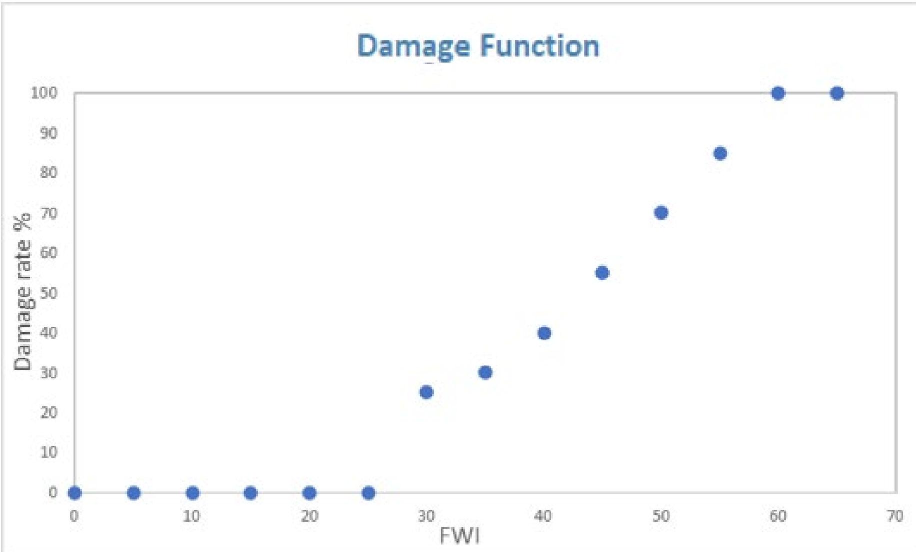
24. The analysis selected geographical areas more likely to experience a fire. As data on fire likelihood was not available, the team used a simplified approach based on WUI and FWI. First, the team used WUI to find locations where residential buildings collateralizing banks' mortgages meet with, or are intersperse within, wildland fuels. Specifically, each CSD and FSA was categorized as meeting wildland fuels if it contained at least one WUI grid. A sensitivity analysis was conducted, changing this definition to CSD and FSA covered by at least 25 percent of WUI. The analysis was further restricted to areas with extreme FWI (i.e. higher than 30), all located in Western Canada (British Columbia, Alberta, Saskatchewan and Manitoba). Many studies find FWI, and its various components, to have a strong predictive ability for fire activity in Canada (Podur and Wotton 2011, Johnston et al. 2020, Jain, Piyush et al. 2024).[20] This is, however, a simplified approach and in reality, wildfires can occur at far lower FWI values in Canada.

25. The FSAP analysis estimated potential damages conditional on a fire. Having restricted the attention to areas where structures meet fuels, and with extreme fire weather, the analysis asks: what if there are wildfires in these areas, assuming that all structures within these areas would encounter a fire and be (at least partially) damaged. The team followed a simplified approach given the lack of wildfire damage functions in Canada. Similar to Erni et al. (2024), the degree of impacts was linked solely to the fire intensity, as proxied by FWI in this case. Damage rates increase with FWI. FWI of 30 implies a damage rate of 25 percent which increases to 100 percent for FWI of 60 (Figure 5). A sensitivity analysis was performed using two different damage functions, that is, a binary function assuming all real estate subject to FWI above 30 would completely be destroyed and a sigmoidal function, which is a common shape of damage functions in the literature (e.g. Lüthi et al. (2021)), assuming a smoother but non-linear increase of damage rates (Figure 5).

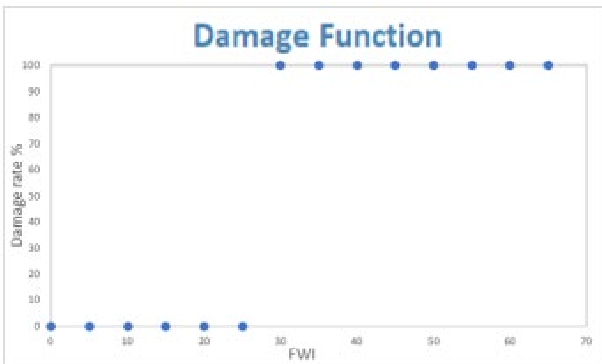
[20] For example, Podur and Wotton (2011) developed and tested an FWI-based definition of spread event on any particular day. Based on their results, they suggest a simple rule of thumb where a spread event, if defined by the probability of a spread day being greater than 0.5, corresponds to an FWI of 19 or above. The authors define a 'spread event' day as "a day when the fire actively spreads (likely with high fire intensity) and adds a sizeable increment to the existing fire area." To be conservative the team adopted a higher threshold of 30.

Figure 5. Canada: Damage Functions

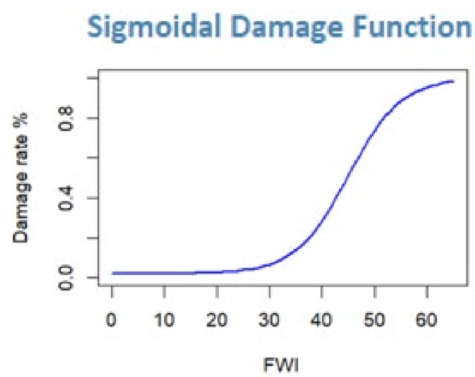
Damage function for main analysis



Damage function for sensitivity analysis (Binary)



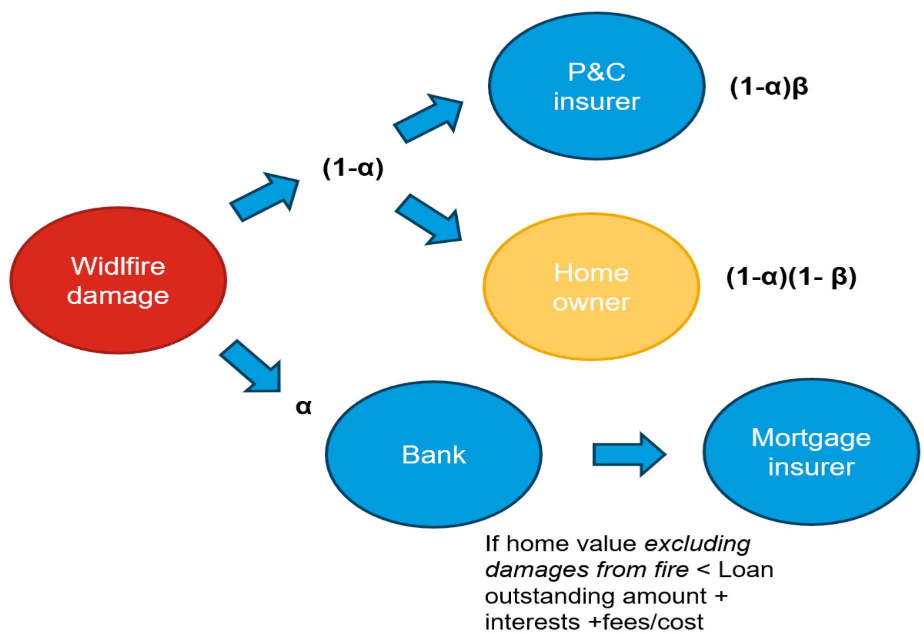
Damage function for sensitivity analysis (Sigmoidal)



Source: IMF Staff.

26. The wildfire damage was linked to DTIs' LGDs, accounting for the role of both mortgage and P&C insurance. The latter would cover a portion of the house's damages, while the former would cover shortfalls of the outstanding loan amount and interest after foreclosure, accounting for the home value excluding damages from fire (Figure 6). In line with Johnston et al. (2023), we assume that mortgage loan insurance excludes unrepaired damages from fires. This assumption is in line with the Canada Mortgage and Housing Corporation (CMHC) practices, one of Canada's largest mortgage insurance providers, which does not cover damages from natural disasters (CMHC 2016). RESL data contains information on whether the loan is mortgage insured. However, no data is available on P&C insurance. This insurance information, despite being requested by banks at the origination of the loans, is not generally monitored by banks throughout the life of the loan (with some exceptions at refinancing) nor collected by the authorities. Given the importance of this data, the FSAP recommends authorities to strengthen the supervision of the adequacy of property insurance protection on the collateral held by banks and insurance companies.

Figure 6. Canada: Wildfire Damages Allocation Across Sectors



Source: IMF Staff.

27. Despite fire insurance being mandatory at mortgage origination, DTIs can still face losses from wildfires. This is due to several factors. Fire insurance does not directly cover mortgage payments on damaged properties in Canada. As reported by the Insurance Bureau of Canada (IBC), "The intent of insurance is to help people recover from the unexpected property losses. It is not intended to cover mortgage payments after a loss or to cover an outstanding mortgage on a home."[21] Further, fire insurance may cover less than the fire damage amount and insurance settlements can take extended periods, especially when wildfires affect a large number of people at

[21] https://www.ibc.ca/stay-protected/severe-weather-centre/wildfire-season

the same time. There are also additional factors that can cause financial distress for borrowers and hence DTIs in the aftermath of a wildfire. Wildfires can have potential adverse economic impacts, for example on jobs in disrupted industries or regions where the labor market is already weak (Duprey et al. (2024)). Homes in high-risk wildfire areas experience negative, but transient and localized, price shocks after a wildfire (Contat et al. (2024)). This can lead to additional stress for households' income. Furthermore, if the mortgage is non-recourse (for the provinces of Alberta and Saskatchewan) the bank can only foreclose on the house and cannot pursue the borrower's other assets and income. Finally, insurance companies might start pulling out from certain markets or substantially increase their premium leaving borrowers without ongoing coverage.

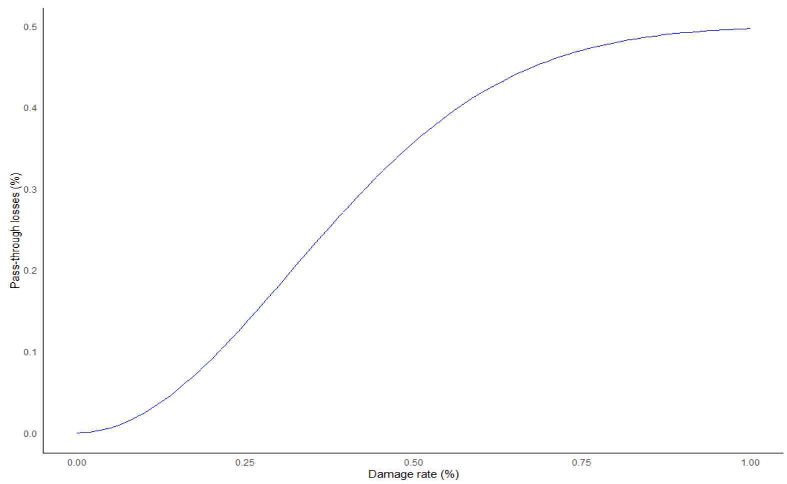
28. There is some empirical evidence that delinquencies and foreclosures increase in regions exposed to severe wildfires. A recent study from the Bank of Canada, Ho *et al.* (2023), finds that the 2016 Fort Mc Murray wildfire had substantial impact on mortgage delinquencies. The authors report a doubling of mortgage arrears in severely damaged areas. This effect dissipated between 12 and 18 months after the event. The results do not depend on the existence of mortgage insurance.

29. The FSAP analysis assumes that a portion (α) of wildfire damages is passed on to DTIs. Given the empirical findings cited above, this portion is modelled as a non-linear function of the wildfire damage rate (Figure 7). That is, small damages are largely absorbed by homeowners and P&C insurance, while for larger damages, there is a higher pass-through of losses to DTIs. In the case of complete destruction of the residential real estate, 50 percent of the loss is passed on to DTIs. The FSAP also ran two sensitivity analyses where the maximum pass-through rate is increased to 75 percent (one using the same functional shape and one assuming a convex shape, see Figure 7). The remaining portion of damages, (1- α), is in part covered by P&C insurance (by a percentage β) and in part absorbed by homeowners (by a percentage (1- β)).[22] Given the lack of data on P&C insurance, the analysis assumed β equal to 80 percent.

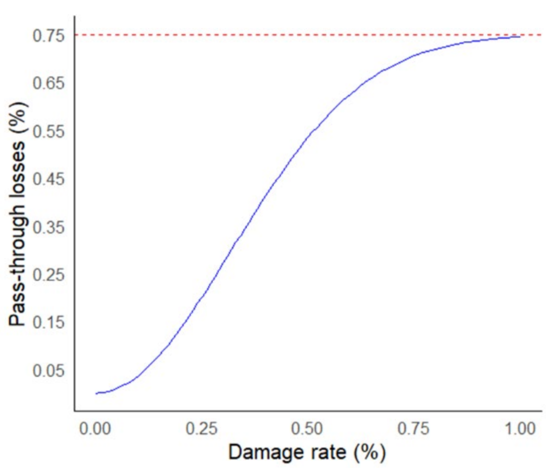
[22] In practice, the P&C insurer would also be covered by reinsurance but the analysis abstracts from this aspect in the model.

Figure 7. Canada: Pass-Through Function of Wildfire Damages to Deposit Taking Institutions

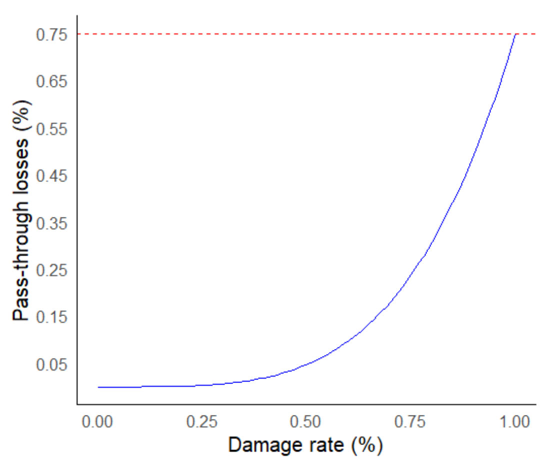
Alpha function for main analysis (50 percent maximum pass-through)



Alpha function for sensitivity analysis (75 percent maximum pass-through)



Alpha function for sensitivity analysis (75 percent maximum pass-through and convex shape)



Sources: IMF Staff.

30. Following Johnston et al. (2023), DTIs' LGDs were defined as the gross loss amount (GLA) in excess of net recoverable amount (NRA).

$$LGD = \begin{cases} GLA - NRA, \; if \; GLA > NRA, \\ 0, \; if \; GLA \leq NRA. \end{cases}$$

The net recoverable amount is what the DTI can recover from the sale of the property net of fees, real estate commissions and depreciation post-fire (Table 2):

$$NRA = \max\left(property\ value \ * \ (1 - depreciation) * (1 - real\ estate\ commission) - apprisal\ fee, 0\right).$$

The gross loss amount depends on mortgage insurance (MI), which covers losses from outstanding balances, accrued interests until settlement and the costs of holding the defaulted property if these exceed the amount recovered from the sale of the property excluding damages from wildfire:

$$MI = max\ ((loan\ unpaid\ balance + accrued\ interests\ until\ settlement + property\ value * (property\ tax + maintenance\ rate + property\ insurance\ cost) + legal\ cost + fixed\ maintenance\ cost - property\ value * (1 - depreciation) * (1 - real\ estate\ commission) - appraisal\ fee).$$

Hence, if the loan is covered by mortgage insurance the gross loss amount is:

$$GLA = \alpha * wildfire\ damage + (loan\ unpaid\ balance + accrued\ interests\ until\ settlement + property\ value * (property\ tax + maintenance\ rate + property\ insurance\ cost)) + legal\ cost + fixed\ maintenance\ cost - MI,$$

otherwise:

$$GLA = \alpha * wildfire\ damage + (loan\ unpaid\ balance + accrued\ interests\ until\ settlement + property\ value * (taxes\ \&\ other\ costs)).$$

Table 2. Canada: Key Wildfire Risk Model Parameters

Parameter	Value
Max α	50 percent
β	80 percent
House depreciation	10 percent
Real estate commission	5 percent
Appraisal fee	500 CAD
Time to settlement	18 months
Property tax	2 percent
Maintenance rate	1 percent
Property insurance cost	3 percent
Legal cost	5,000 CAD
Fixed maintenance cost	2,000 CAD

Source: IMF Staff, Johnston et al. (2023).

Note: The parameters have been set in line with the authorities' flood risk stress test analysis Johnston et al. (2023).

31. This analysis is subject to several caveats and limitations, given data availability. Most importantly, it only focuses on the impact of climate on one driver of wildfires, namely fire weather. It does not account for changes in fuels and ignitions. The analysis does not account for the likelihood of fires, and it adopts a proxy of fire intensity (FWI) to study the potential impact of wildfires conditional on a fire event. Given the coverage of wildfire risk for the entire country and the geospatial granularity of RESL data, the analysis lacks the geographical granularity of micro-scale studies. Further, the exposure data does not change over time, and the dataset for WUI is not up to date as the latest update is based on 2019 data for structures. The mapping of WUI to CSDs is also subject to uncertainties, and results are highly sensitive to the chosen mapping method. Damages are computed under a reduced form approach assuming that, conditional on a fire, higher FWI implies higher damages. In reality this is not always the case. The actual damage will depend on many other factors, such as the region considered, fuels, fire regimes, land management policies and mitigation/suppression capabilities and past fire experience. The analysis estimates losses conditional on defaults and does not model probabilities of default.

32. The FSAP analysis is likely to underestimate potential losses from physical risks. First, the physical risk exposure analysis investigates the combined mortgage portfolio of all banks in the sample, due to data confidentiality reasons. While the combined portfolio of all banks may have diversified exposures across Canada, individual banks may have more concentrated exposures—not identifiable in the dataset. Hence, concentration of exposures could be underestimated by this approach. Furthermore, the wildfire risk analysis focuses on a specific credit risk channel and only captures direct impacts, ignoring indirect and systemic effects. Lastly, the analysis only covers one hazard, while other hazards and their compounding effects are also relevant. For example, the analysis does not capture wildfire-drought cycles, where wildfires exacerbate droughts by damaging vegetation and reducing soil moisture, which in turn can lead to more severe wildfires.

33. Despite these caveats and limitations, this study is a useful starting point. The authorities have not conducted a full wildfire risk assessment yet. Hence, they could leverage this framework to advance their future work in this area. This is also the first time that a full wildfire risk analysis is included in an FSAP. This analysis leverages the data and expertise available in Canada, a country with a long history of research on wildfires. Over time, with more data and knowledge developed in this area, IMF Staff will build and improve upon this wildfire risk analysis framework.

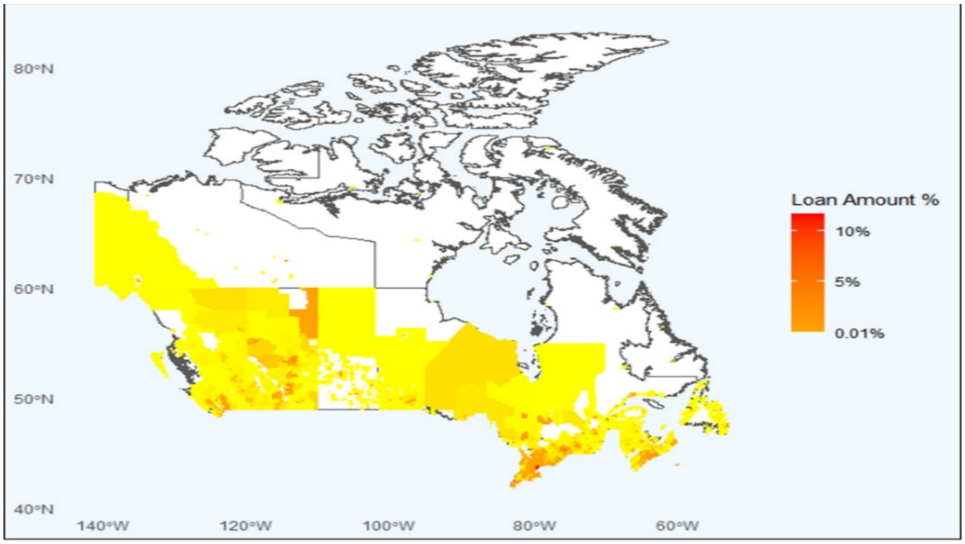
Results—Exposure Analysis

34. At the DTI sector level, the pool of residential real estate mortgages is geographically diversified across Canada. The combined portfolio of the 6 D-SIBs is broadly diversified (Figure 8), with few concentrated exposures. One CSD in Toronto with a land area of 631 Km^2 contains 11.6 percent of the total loans across Canada. The other top ten most concentrated CSDs are located in Calgary, Brampton, Ottawa, Mississauga, Vancouver, Montreal, Surrey, Edmonton and Hamilton (Figure 8).

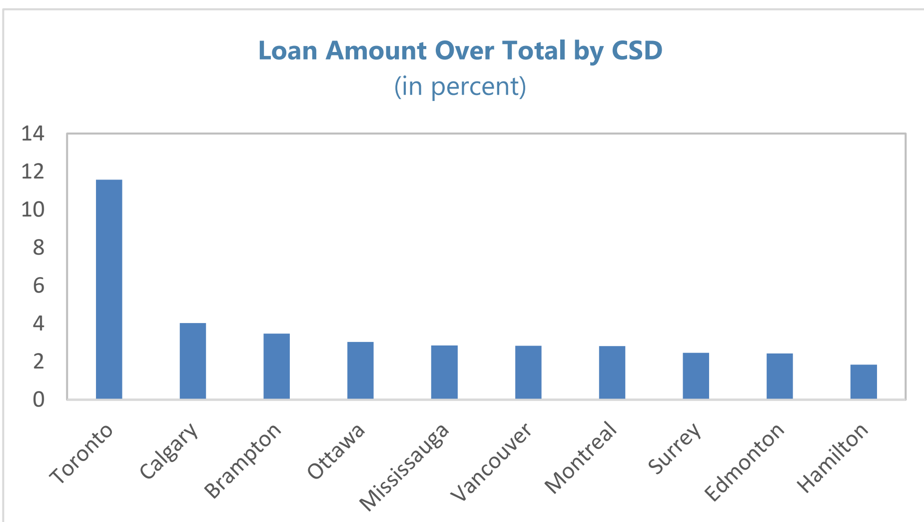
Figure 8. Canada: Residential Real Estate Secured Lending Loan Amount in Census Subdivision Over Total Loan Amount in Canada

(in percent)

All CSDs



Top 10 CSDs



Sources: OSFI RESL data and IMF Staff computation.

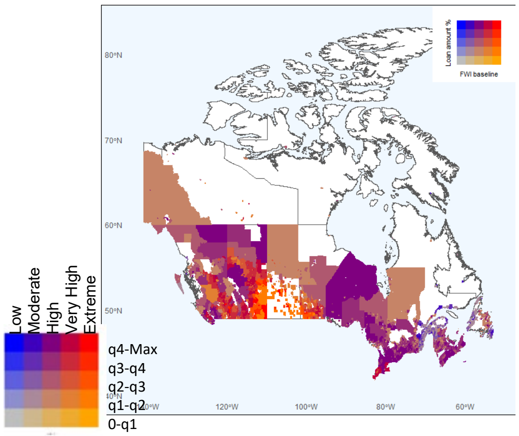
35. This pool of mortgages is exposed to noticeable climate-related wildfire risks. A significant portion of loans is located in areas with very high or extreme FWI, and this portion increases with climate change under both medium and high-emissions scenarios (Figure 9 and Table 3). Similar pictures arise when looking at BUI and FSL (Figures 10 and 11), with even larger percentages of loans located in high-risk buckets (Table 3).

Table 3. Canada: Total High-Risk Loan Amount by Wildfire Risk Indicator (in percent)					
Total loan amount ≥ 75th percentile and	**Historical baseline**	**RCP 4.5 2041-2070**	**RCP 4.5 2071-2100**	**RCP 8.5 2041-2070**	**RCP 8.5 2071-2100**
FWI >20	45	77	77	77	79
BUI > 60	64	83	83	83	85
FSL > 200	86	97	97	98	98
Sources: OSFI RESL data and CanLEAD— FWI dataset from ECCC, IMF Staff computations.					

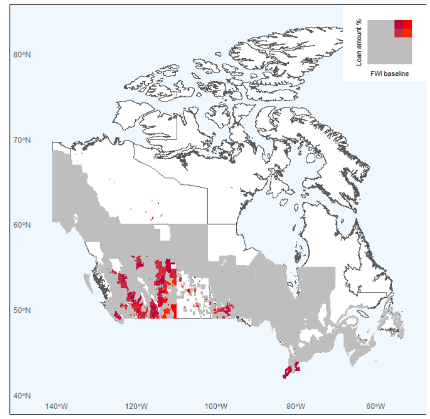
36. Already by mid-century a significant portion of loans migrates to very-high and extreme fire-weather under both RCP 4.5 and RCP 8.5. Looking at the distribution of the aggregate portfolio for the 7 systemic DTIs categorized by FWI, BUI and FSL (from low to extreme), the analysis finds a significant shift to the right-tail by mid-century (Figure 12). The shift is even more pronounced by the end-of-century under RCP 8.5. Specifically, under both scenarios, 65 percent of loans will be located in areas subject to very high and extreme fire weather in mid-century, relative to 38 percent in the historical baseline. The majority of loans are already exposed to "very high" BUI. More than 25 percent of loans will become exposed to "extreme" BUI under RCP 4.5 and RCP 8.5, relative to 9 percent in the historical baseline. Under these scenarios, DTIs' residential real estate collateral will also be exposed to longer fire seasons. By mid-century, 90 percent of loans will be exposed to fire seasons longer than 200 days under both scenarios, relative to 70 percent of loans under the historical baseline. The migration is even more into the tail under RCP 8.5, with 57 percent of loans exposed to fire seasons longer than 250 days by 2100, relative to 21 percent under RCP 4.5.

Figure 9. Canada: Real Estate Secured Lending Loan Amount in Census Subdivision vs Fire Weather Index

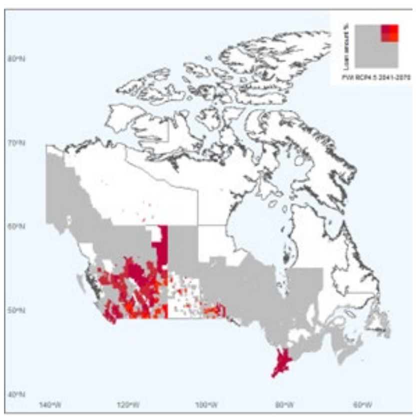
Historical baseline—all loans



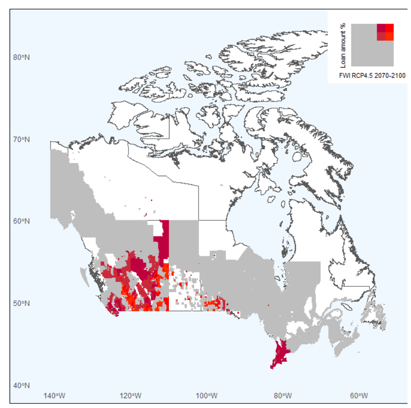
Historical baseline—only "high risk" loans



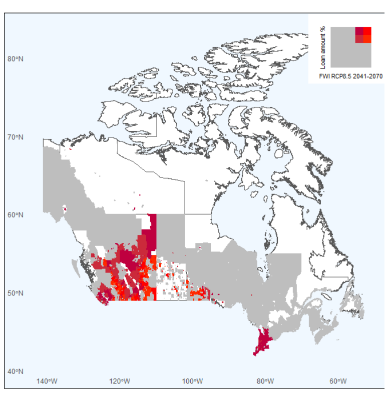
RCP 4.5 mid-century



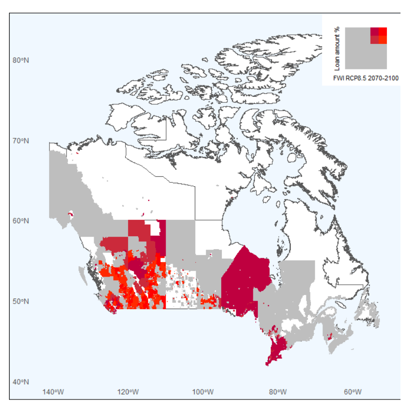
RCP 4.5 end of the century



RCP 8.5 mid-century



RCP 8.5 end of the century

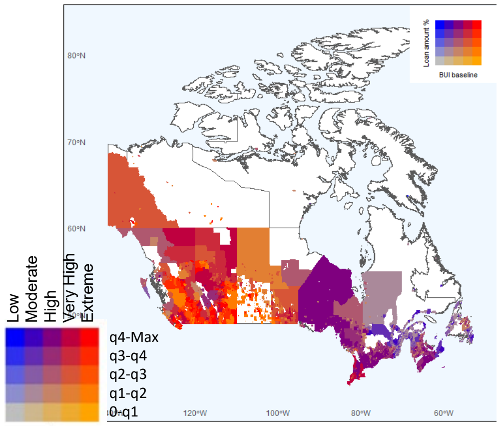


Sources: OSFI RESL data, CanLEAD—FWI dataset from ECCC, and IMF Staff computations.

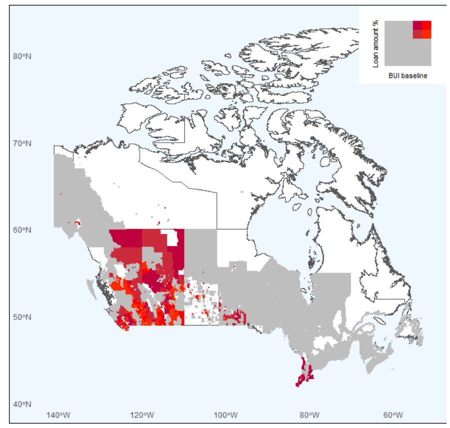
Notes: The figures show the 6 D-SIBs' mortgages by Census Subdivisions categorized by FWI levels (from low to extreme) and loan amount in percentage over the total (from the first quantile q1 to the fourth q4). FWI≤5 is considered low, 5<FWI≤10 moderate, 10<FWI≤20 high, 20<FWI≤30 very high, FWI>30 extreme.

Figure 10. Canada: Real Estate Secured Lending Loan Amount in Census Subdivision vs Buildup Index

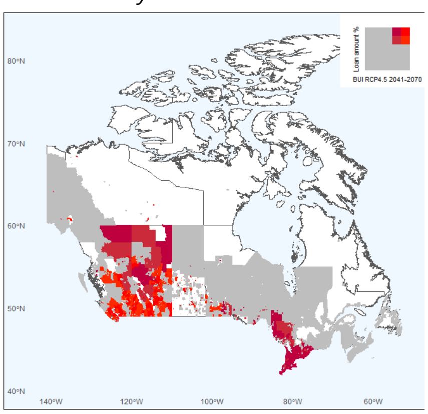
Historical baseline—all loans



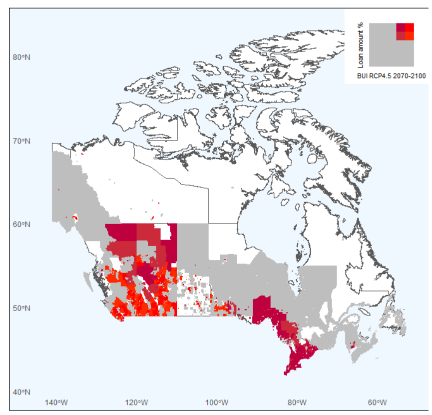
Historical baseline—only "high risk" loans



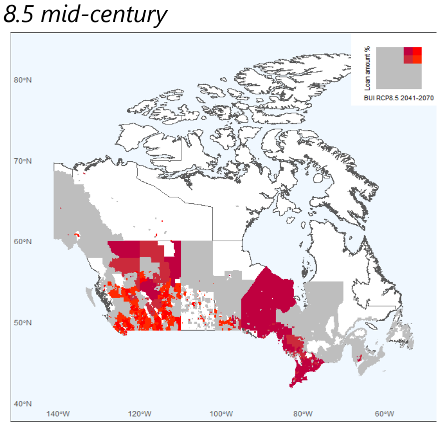
RCP 4.5 mid-century



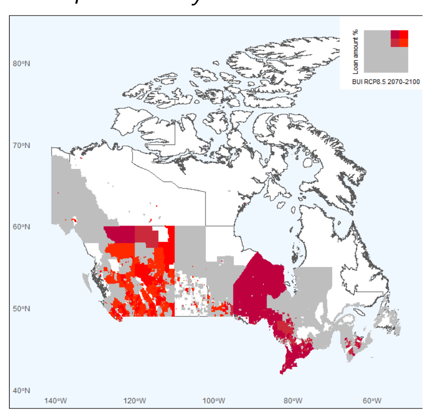
RCP 4.5 end of the century



RCP 8.5 mid-century



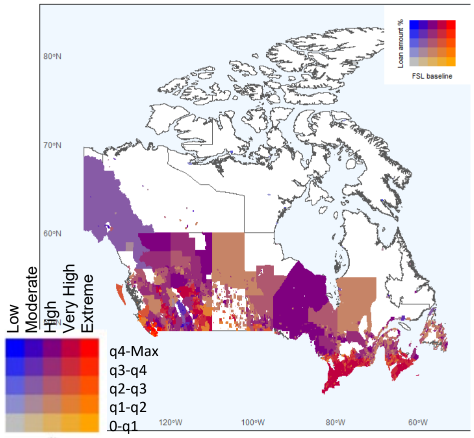
RCP 8.5 end of the century



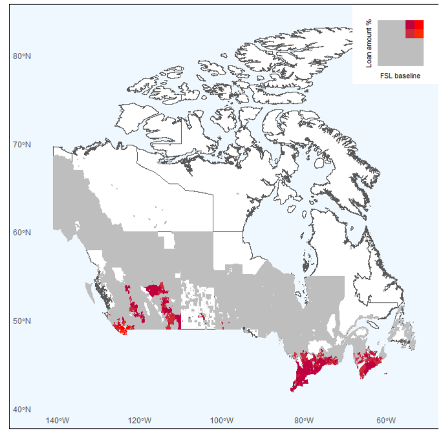
Sources: OSFI RESL data, CanLEAD-FWI dataset from ECCC, and IMF Staff computations.
Notes: The figures show the 6 D-SIBs' mortgages by Census Subdivisions categorized by BUI levels (from low to extreme) and loan amount in percentage over the total (from the first quantile q1 to the fourth q4). BUI≤20 is considered low, 20< BUI ≤40 moderate, 40< BUI ≤60 high, 60< BUI ≤90 very high, BUI >90 extreme.

Figure 11. Canada: Real Estate Secured Lending Loan Amount in Census Subdivision vs Fire Season Length

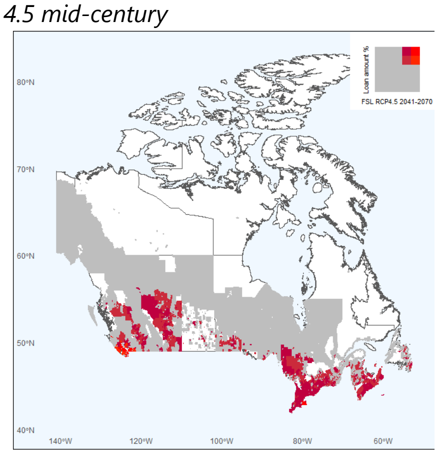
Historical baseline—all loans



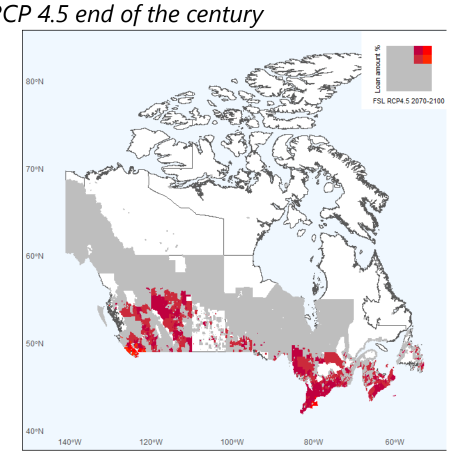
Historical baseline—only "high risk" loans



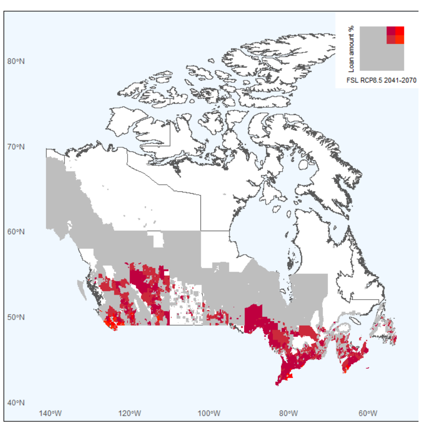
RCP 4.5 mid-century



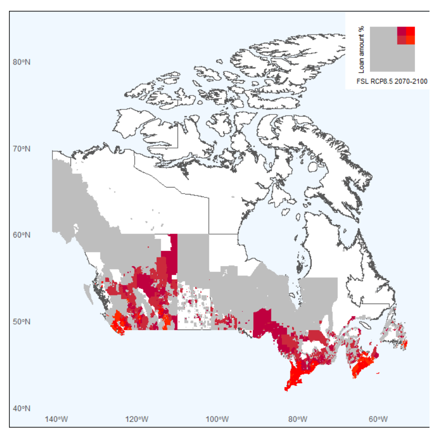
RCP 4.5 end of the century



RCP 8.5 mid-century



RCP 8.5 end of the century

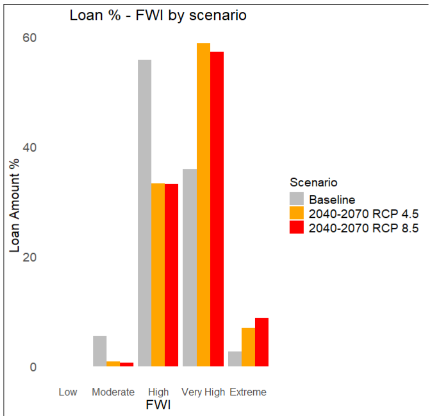


Sources: OSFI RESL data, CanLEAD-FWI dataset from ECCC, and IMF Staff computations.

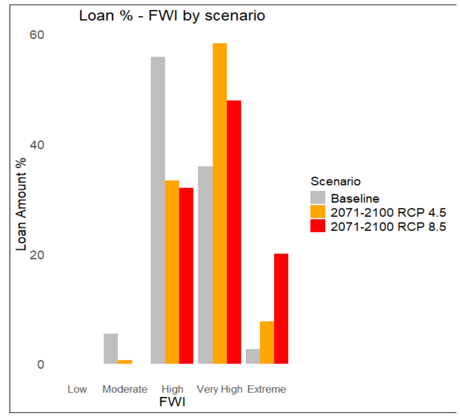
Notes: The figures show the 6 D-SIBs' mortgages by Census Subdivisions categorized by FSL levels (from low to extreme) and loan amount in percentage over the total (from the first quantile q1 to the fourth q4). FSL≤100 is considered low, 100<FSL≤150 moderate, 150<FSL≤200 high, 200<FSL≤250 very high, FSL>300 extreme.

Figure 12. Canada: Real Estate Secured Lending Loan Amount Distribution by Wildfire Risk Indicators

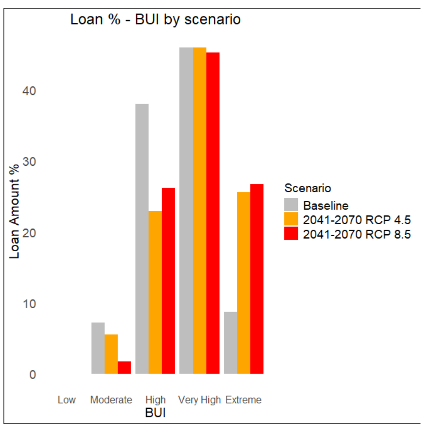
FWI mid-century



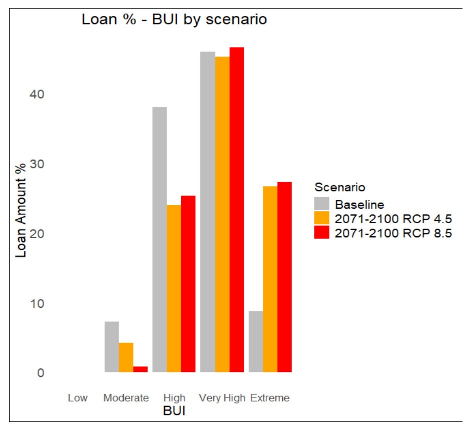
FWI end of the century



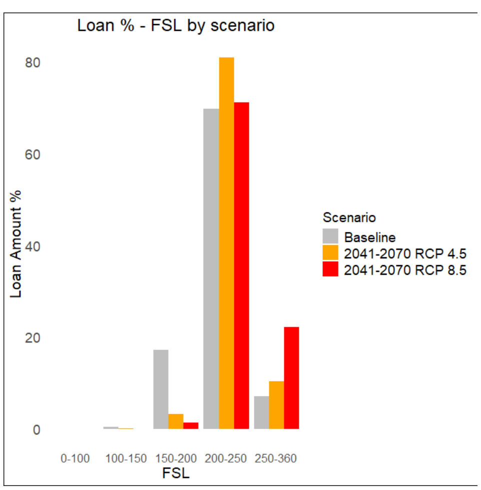
BUI mid-century



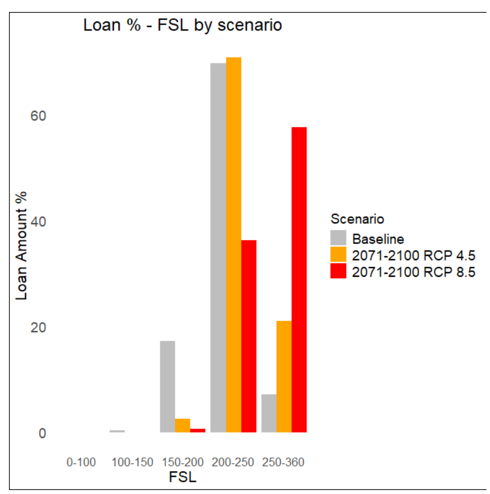
BUI end of the century



FSL mid-century



FSL end of the century



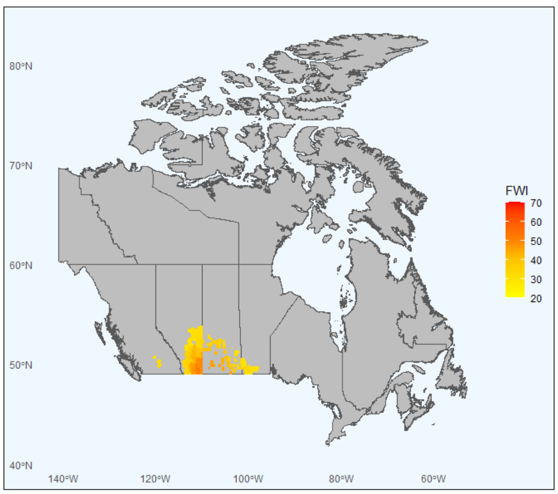
Sources: OSFI and AMF RESL data, CanLEAD-FWI dataset from ECCC, and IMF Staff computations.

Results—Risk Analysis

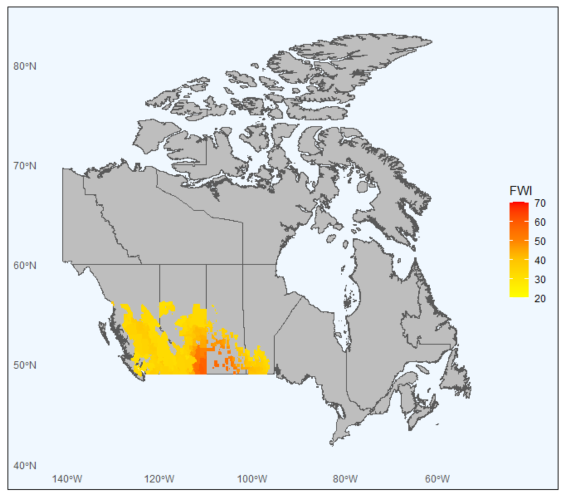
37. **Based on the FSAP methodology, geographical areas more likely to experience a fire are located in Western Canada** (Figure 13). Four provinces (British Columbia, Alberta, Saskatchewan and Manitoba) where DTIs' lending is collateralized by residential real estate, are identified as more likely to experience a fire, as they contain WUI areas and are exposed to extreme fire weather (FWI higher than 30). Within these provinces, areas identified as more likely to experience a fire expand as we move from the historical baseline (187 CSDs) to RCP 8.5 at the end of the century (616 CSDs). This is due to more areas becoming exposed to extreme fire weather. Under the historical scenario, 2.9 percent of all RESL loans are located in these areas. Under RCP8.5 at the end of the century, the share of affected loans rises to 22.6 percent.

Figure 13. Canada: Fire Scenarios

Fire scenario—Baseline



Fire scenario—RCP 8.5 end of the century



Sources: RESL data, WUI data, FWI data, and IMF Staff computation.

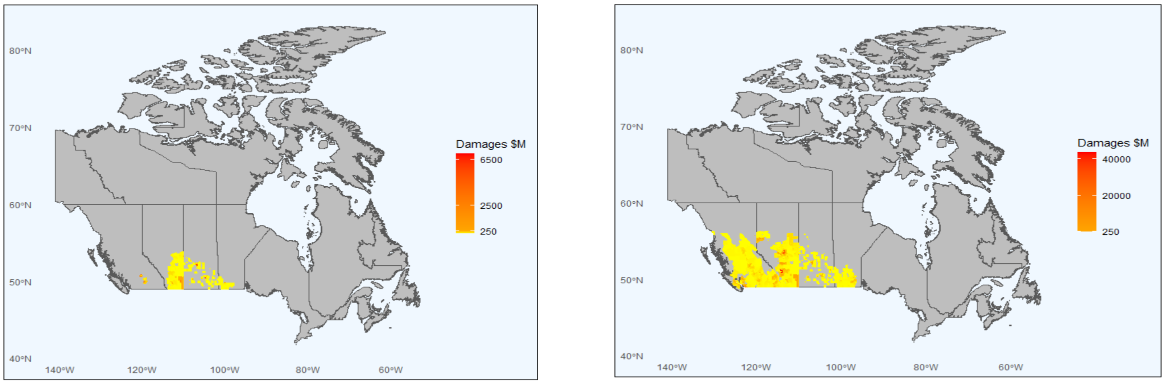
Note: the figures depict the areas identified as more likely to experience a fire under the historical baseline (Left Hand Side) and RCP 8.5 scenario at the end of the century (Right Hand Side). The color scheme shows FWI in each of these areas. Grey areas were not identified as more likely to experience a fire under the adopted methodology and hence excluded from the fire scenarios.

38. **Conditional on fires erupting in these areas, total damages to residential real estate would be considerable.** Total damages are 38 CAD billion in the baseline. Damages would increase by around 2.5 times under RCP 4.5 and around 7.3 times reaching 278 CAD billions under the more severe scenario RCP 8.5 at the end of the century (Figure 14). These numbers should not be interpreted as the total expected losses, but only as hypothetical estimates of residential real estate value at risk. These estimates are based on the assumption that all at-risk-areas would be affected at the same time, which is not entirely realistic and possibly leads to over-estimation of losses.[23]

[23] By comparison, Wang et al. (2020) projects increases in burn area in Canada for the same time period and scenario, grounded in empirical relations between fire weather and fire size, up to 4.3 times relative to the baseline.

Figure 14. Canada: Wildfire Damages to Residential Real Estate

Fire damages – Baseline *Fire damages - RCP 8.5 end of the century*



Sources: RESL data, WUI data, FWI data, and IMF Staff computation.

Note: the figures depict the areas identified as more likely to experience a fire under the historical baseline (LHS) and RCP 8.5 scenario at the end of the century (RHS). The color scheme shows estimated wildfire damages to residential real estate in each of these areas. Grey areas were not identified as more likely to experience a fire under the adopted methodology and hence excluded from the fire scenarios.

39. **DTIs' losses conditional on defaults would increase significantly with climate change under the most severe scenario.** The increase in aggregate LGDs of affected loans in Western Canada under future climate scenarios relative to the baseline ranges from 1.6 percentage points (PP) under RCP 4.5 in mid-century to 6.4 PP under RCP 8.5 at the end of the century (Figure 15).

40. **Loans with high LTV are significantly more sensitive to wildfire-driven losses.** Aggregate results mask vulnerabilities of more risky loans. The median LTV of affected loans is relatively low (42 percent under RCP 8.5 at the end of the century), muting the impact of wildfires damages on the DTI sector. The increase in LGDs for loans with LTV above 80 percent is significantly higher than for the rest. These households possess lower equity, which reduces their ability to absorb shocks such as wildfires when they occur. However, loans with LTV above 80 percent constitute only a small percentage of total loans in Western Canada (Figure 15).[24]

41. **Some provinces are significantly more affected than others due to variations in fire weather conditions.** LGDs of loans located in Saskatchewan increase up to 17.5 PP under RCP 8.5 by the end of the century relative to the historical baseline. This province is exposed to higher fire weather relative to the other provinces. As a result, property located in Saskatchewan suffer larger damages, and these damages increase even more under future climate (Figure 16).

42. **Given the assumed insurance coverage, exposures for the P&C insurance sector are large** (Figure 15). By assumption, a significant portion of damages is absorbed by the P&C insurance sector. Due to lack of P&C insurance data, the FSAP analysis assumed that P&C insurance covers

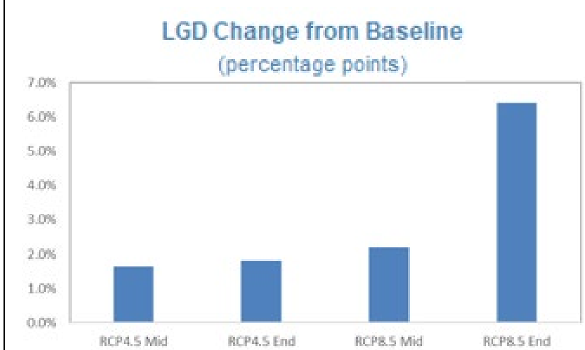
[24] LTV ratio on a property is computed as the total outstanding balance on the property plus 75 percent of the unused authorized credit amount divided by the property appraisal value updated to September 2023. This is in line with the approach followed by the authorities in Johnston et al. (2023).

80 percent of the damages not passed on to DTIs. If the P&C insurance sector absorbs a smaller portion of wildfire damages, more losses will be passed on to DTIs.

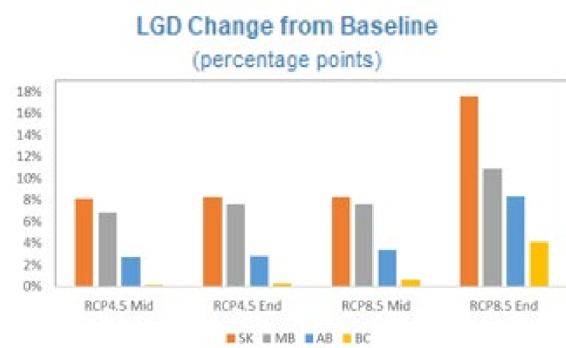
43. Exposures for the mortgage insurance sector are relatively small (Figure 15). Only 24 percent of loans in Western Canada have mortgage insurance. Further, mortgage insurance covers only shortfalls of the outstanding loan amount and interest after foreclosure, accounting for the home value *excluding* damages from fire. That is, mortgage insurance only pays out if the loan is underwater excluding fire damages. Since LTVs are generally low, these shortfalls are rare and small overall.

Figure 15. Canada: Wildfire Risk Analysis Results

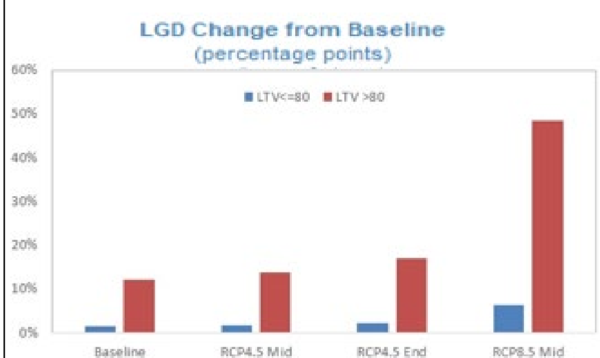
Aggregate LGD change from baseline (Western Canada)



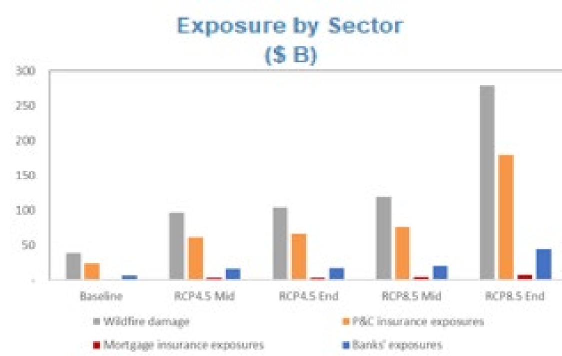
LGD change from baseline by province



LGD change from baseline by LTV



Exposures by sector

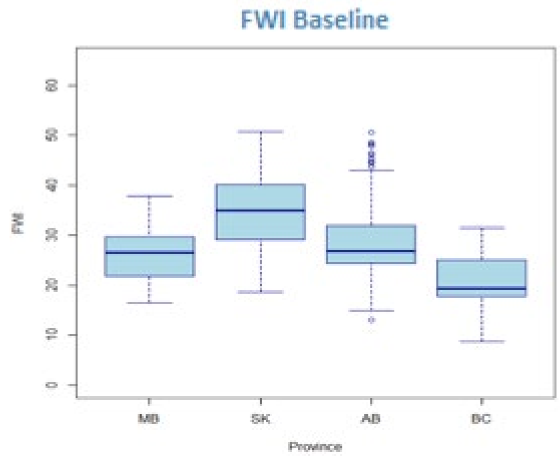


Sources: RESL data, WUI data, FWI data, and IMF Staff computation.

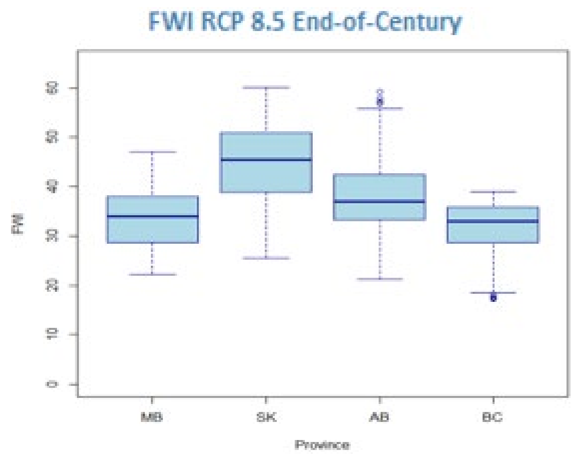
Note: provinces names have been abbreviated. SK stands for Saskatchewan, MB for Manitoba, AB for Alberta and BC for British Columbia. "Mid" stands for mid-century and "End" for end of the century.

Figure 16. Canada: Drivers of Damages by Provinces

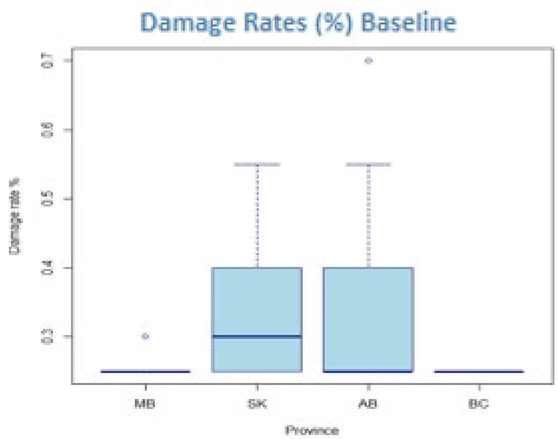
FWI by provinces—Baseline



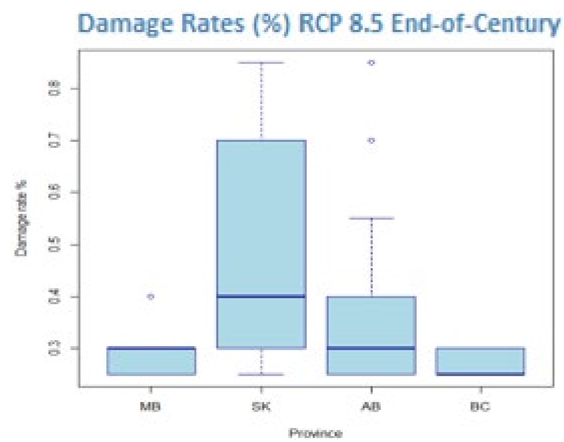
FWI by provinces—RCP 8.5 end of century



Damage rates by provinces—Baseline



Damage rates by provinces—RCP 8.5 end of century



Sources: RESL data, WUI data, FWI data and IMF Staff computation.

Note: provinces names have been abbreviated. SK stands for Saskatchewan, MB for Manitoba, AB for Alberta and BC for British Columbia.

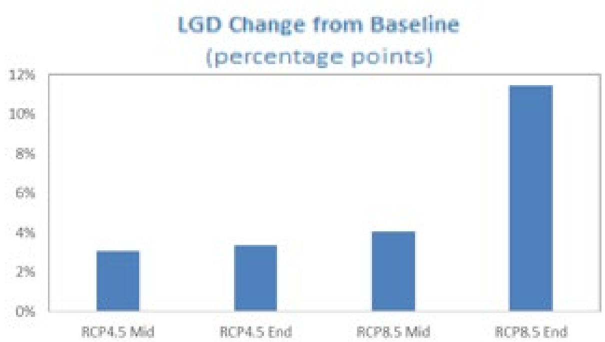
44. Increasing the pass-through rate to DTIs leads to substantially larger LGDs. By contrast, a more convex function (i.e., high pass-through only for higher damage rates) lowers DTIs' LGDs (Figure 17). If DTIs' losses increase (decrease), P&C insurance exposures decrease (increase). This is an important point to highlight, given that insurance companies could start pulling out from certain markets, or substantially increase their premiums in the future, if faced with increasing claims. Systemic risk analysis of physical risks should ideally take into account the interlinkages between the banking (and deposit-taking) sector and the insurance sector.

45. The results are highly sensitive to the damage function adopted. Given the lack of a wildfire damage function for Canada, the FSAP team experimented with different functions. For example, if all houses experiencing a fire were to be destroyed completely, DTIs' losses would be significantly higher. On the other hand, if damages were to increase significantly only for extremely high FWI, DTIs' losses would be lower (Figure 18). As above, if DTIs' losses increase (decrease), P&C insurance claims decrease (increase).

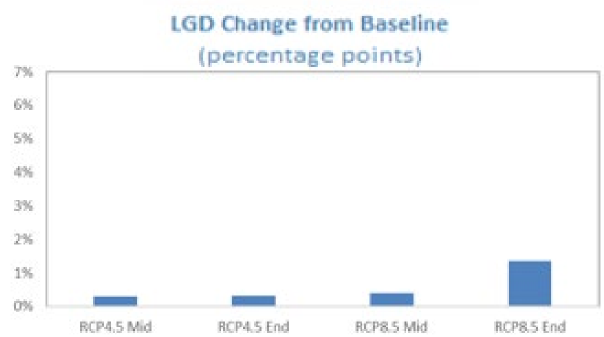
46. The results depend heavily also on how wildland urban interfaces are mapped to DTIs' loans. In the main analysis each loan's CSD and FSA was categorized as meeting wildland fuels if it contained at least one WUI grid. This generous definition identified 97 percent of RESL loans as meeting wildland fuels. A sensitivity analysis was conducted, changing this definition to CSD and FSA covered by at least 25 percent of WUI. Under this stricter definition, a smaller amount of RESL (23 percent of total) would be considered as meeting wildland fuels, and hence potentially at wildfire risk. As a result, banks' LGDs would be smaller, as well as overall wildfire damages (Figure 19). This sensitivity analysis highlights the importance of using granular geospatial data. Unfortunately, the FSAP team had only access to relatively aggregated geographical information for RESL which prevented a more refined mapping with WUI.

Figure 17. Canada: Pass-Through Rate Sensitivity Analyses

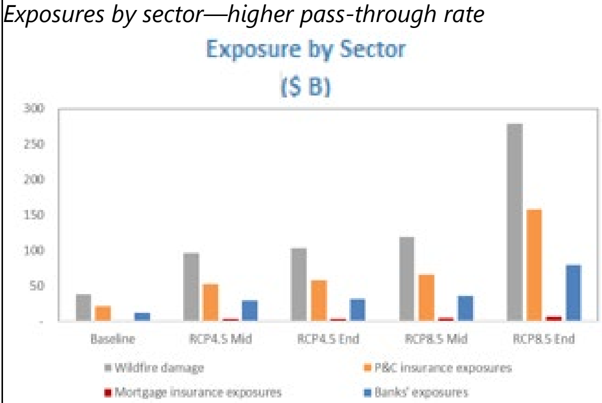
LGD change from baseline—higher pass-through rate



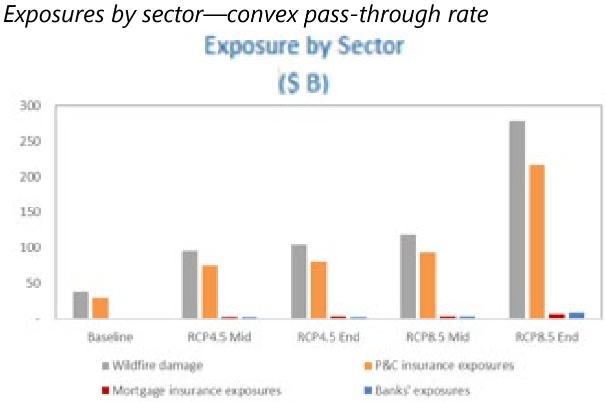
LGD change from baseline—convex pass-through rate



Exposures by sector—higher pass-through rate



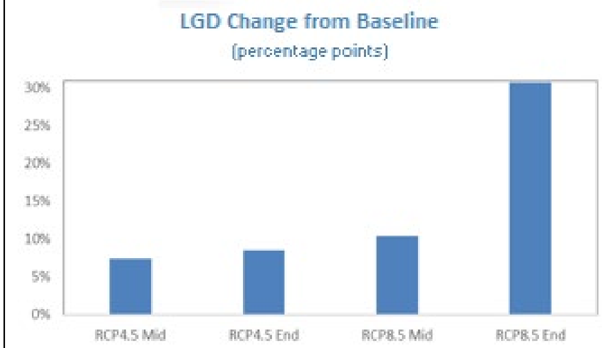
Exposures by sector—convex pass-through rate



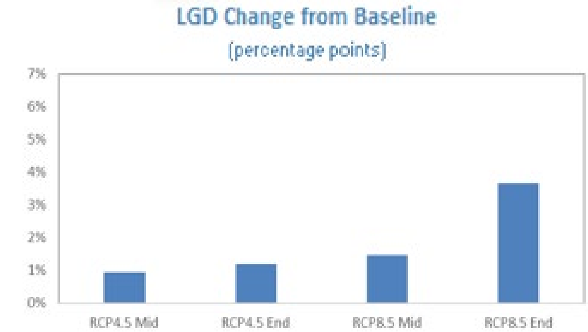
Sources: RESL data, WUI data, FWI data and IMF Staff computation. "Mid" stands for mid-century and "End" for end of the century.

Figure 18. Canada: Damage Function Sensitivity Analyses

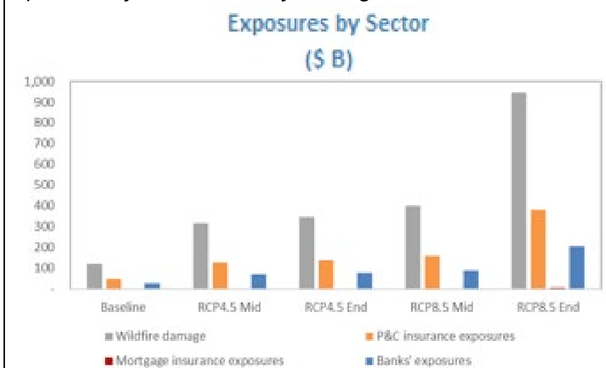
LGD change from baseline—binary damage function



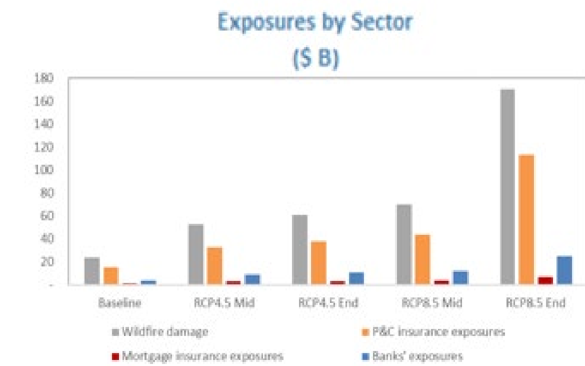
LGD change from baseline—sigmoidal damage function



Exposures by sector—binary damage function



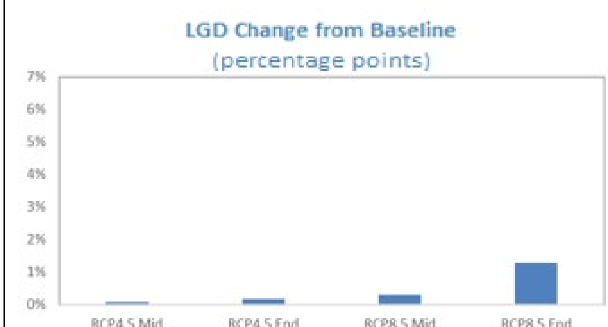
Exposures by sector—sigmoidal damage function



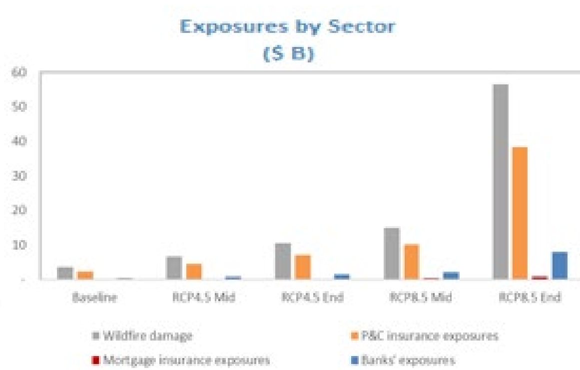
Sources: RESL data, WUI data, FWI data and IMF Staff computation. "Mid" stands for mid-century and "End" for end of the century.

Figure 19. Canada: Wildland-Urban Interface Sensitivity Analyses

LGD change from baseline—CSD > 25 percent of WUI



Exposures by sector— CSD > 25 percent of WUI



Sources: RESL data, WUI data, FWI data and IMF Staff computation. "Mid" stands for mid-century and "End" for end of the century.

TRANSITION RISK ANALYSIS

A. Transition Risks in Canada

47. Canada is exposed to transition risks as a major fossil fuel producer. Canada is the tenth largest global emitter. A large share of Canada's greenhouse gas emissions (GHG) is from the oil and gas sector, followed by transport and buildings (Figure 20). Sectors with high emission intensity represent a significant share of output.

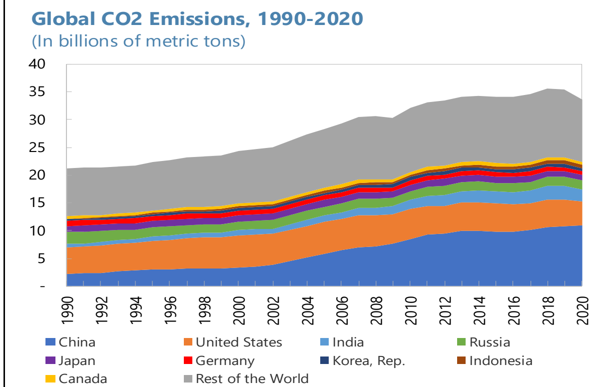
48. Canada has committed to achieve net-zero emissions by 2050 and set milestone targets to reduce emissions by 40–45 percent by 2030 and by 45–50 percent by 2035 relative to the 2005 levels. To this end, Canada has implemented a federal carbon pricing system to reduce GHG emissions. Since 2019, Canada's carbon pricing system included both a federal fuel charge and an industrial pollution pricing system. A federal benchmark for carbon pollution pricing ensures that carbon pricing applies to a broad set of emission sources throughout Canada with increasing stringency over time to reduce GHG emissions. Canada's national price on carbon pollution for explicit price-based systems started at CAD 65 per ton of GHG emissions in 2023 and was intended to increase by CAD 15 per year to CAD 170 per ton CO2e in 2030.[25]

49. Canada has a large set of mitigation policies. These measures encompass broad economic policies, alongside more specific initiatives like vehicle and engine emission regulations, energy efficiency incentives, and sector-specific strategies. For example, Canada plans to phase-out coal generation by 2030 and require a net-zero grid by 2050. The Government of Canada introduced the Clean Fuel Regulations in 2023, requiring gasoline and diesel primary suppliers to reduce the carbon intensity of the gasoline and diesel they produce in and import into Canada over time. The Government committed to developing measures to reduce methane emissions from the oil and gas sector by at least 75 percent relative to 2012 levels by 2030. The Government of Canada's Electric Vehicle Availability Standard establishes annually increasing targets for zero-emission vehicles (ZEV) that require 100 percent of new light-duty vehicles offered for sale in Canada to be ZEVs by 2035, with interim sales targets of 20 percent by 2026 and 60 percent by 2030. The "2 billion Trees" program invests CAD 3.2 billion over 10 years by 2031 to support the Government of Canada's commitment to plant two billion trees across Canada to help achieve the net-zero emission target by 2050.

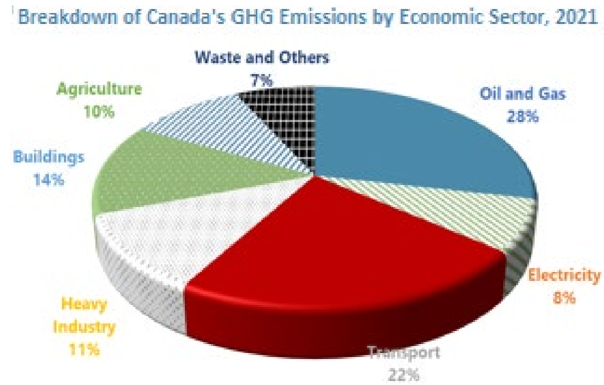
[25] The policies mentioned in this note are up to date as of the end of the main IMF mission on February 24th, 2025. Going forward these policies might change. For example, as of April 2025, the Government of Canada removed the federal fuel charge. The Quebec province own fuel carbon price is still implemented.

Figure 20. Canada: Transition Risks

Canada is exposed to transition risks, being the tenth largest emitter in the world.



A large share of Canada's greenhouse gas emissions is in the oil and gas sector, followed by transport and buildings.



Sources: The World Bank, Canadian Climate Institute.

B. Authorities' Transition Risk Analysis

50. OSFI and BOC started their first pilot transition risk analysis in 2020. The pilot adopted transition scenarios developed by BOC and covered six federally regulated financial institutions (2 banks, two life insurers, two P&C insurers). For banks, the focus was on credit risk for wholesale loans (10 most emission intensive sectors and their sub-sectors). The BOC extended this analysis to cover credit, market and liquidity risks for a larger set of financial institutions, including banks and credit unions, life insurers, pension funds and investment funds (Bruneau et al. 2023).

51. The SCSE has a broader coverage, analyzing credit risk and market risk of global commercial exposures. This exercise, covering most Canadian financial institutions, significantly expands the coverage from the authorities' pilot transition risk analysis. OSFI and AMF developed macro-financial factors for three transition scenarios and 25 industry sectors, using BOC scenarios and data from Moody's Analytics. Participating institutions were asked to use these factors to estimate credit and market risk for their portfolios. The SCSE also includes an exposure assessment of Canadian real estate-related assets, focusing on quantifying exposures to properties powered or heated by carbon-intensive sources.

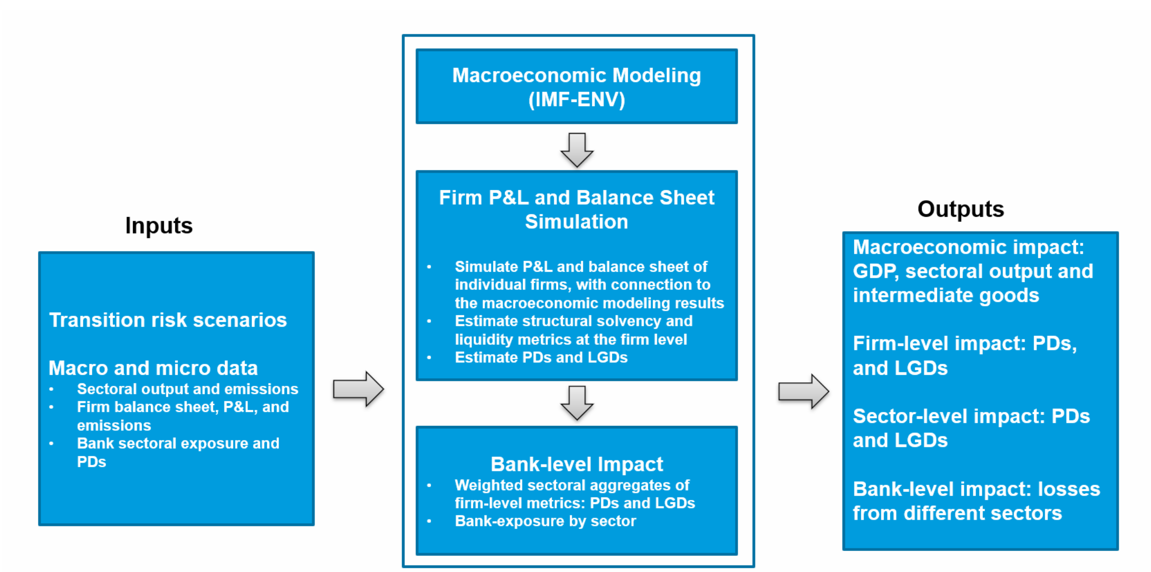
52. Canadian regulators are working towards advancing climate risk management in financial institutions including in analysis of transition risks. The SCSE is a comprehensive and well-designed exercise. Given the standardized nature of the exercise, the framework is very prescriptive. In the future, authorities will benefit from leaving more room for financial institutions' internal data and methodologies. The authorities have already stated that any future climate exercises would rely on financial institutions' internal data and methodologies. The FSAP also recommends moving away from private data vendors towards developing internal datasets, for example to estimate PDs and LGDs under transition scenarios, for other top-down studies and analyses.

C. Financial Sector Assessment Program Transition Risk Analysis

Introduction

53. The transition risk analysis identified potential pressure points from the transition to a low-carbon economy. The analysis adopted an integrated micro-macro approach following Gross et al. (forthcoming) and its application in the 2024 Japan FSAP. The IMF-ENV model was used to derive scenario-conditional paths for macroeconomic and sectoral variables up to 2040 and a micro simulation connected those variables to balance sheets of NFCs and banks (Figure 21).[26] The focus of the analysis was to estimate the potential impact of the transition for the 7 systemic DTIs in terms of credit risk from NFCs.

Figure 21. Canada: Integrated Micro-Macro Modeling Framework



Source: IMF Staff.

Scenarios

54. Three scenarios were considered: CP (the baseline scenario), orderly transition ("Net Zero 2050") and disorderly transition ("Delayed Transition"). The transition scenarios align with those of the Network for Greening the Financial System (NGFS) Phase IV. The scenarios also incorporate Canada specific policies (carbon pricing and others mentioned above, see also footnote 26.

- **Current policies (CP):** only currently implemented policies up to end-2023 are taken into account and are assumed stay in place until the end of the simulation period (2040).

[26] The scenario simulations do not extend beyond 2040 due to modelling constraints.

- **Net Zero 2050 (NZ)** limits global warming to 1.5˚C through stringent climate policies and innovation, reaching global net zero CO_2 emissions around 2050.

- **Delayed transition (DT)** assumes annual emissions do not decrease until 2030. Strong policies are needed from 2031 onwards to reach Net Zero in 2050 on an accelerated timeline.

55. Scenarios were calibrated using the IMF's global dynamic computable general equilibrium (CGE) model. The model is called IMF-ENV and is based on the ENVISAGE model (Van der Mensbrugghe, 2024) and the OECD's ENV-Linkages model (Chateau et al. 2014). The IMF-ENV model features a detailed description of energy production and consumptions, and links between economic dynamics and GHG emissions (Chateau et al. 2025). The model outputs include both country level and sectoral variables.[27]

56. In the Net Zero 2050 scenario, emissions in 2030 achieve a 45 percent reduction with respect to the historical 2005 emissions, in line with Canada's Nationally Determined Contributions (NDC) target for 2030. From 2031 onwards emissions decrease to reach zero in 2050. In the DT scenario CP emissions are kept fixed until 2030, afterwards emissions decline to reach the same 2040 target emission level of the Net Zero 2050 scenario (Figure 22).

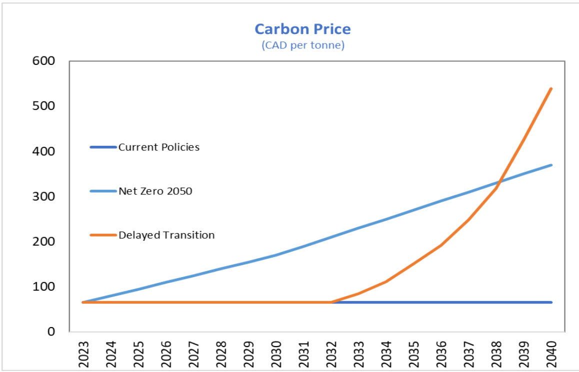
57. Macro impacts by 2040 are somewhat greater under the DT scenario compared to the Net Zero 2050 scenario. Under the DT scenario, carbon prices would need to accelerate sharply and surpass those in the Net Zero scenario as we approach mid-century (Figure 22). In all scenarios, it is assumed that the revenue generated by the carbon price is transferred back entirely to households.[28]

[27] Specifically, IMF-ENV incorporates 36 different sectors. For the FSAP analysis these sectors were mapped to the sectoral classification specified in Figure 23, based on available firms and DTIs' data.

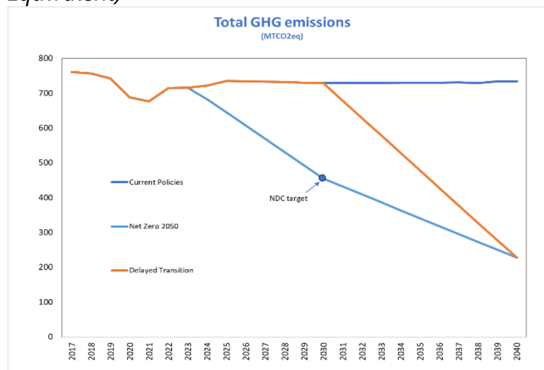
[28] This is a simplification which is broadly in line with the system in place in Canada. The Government of Canada states that: "All money (proceeds) from the federal fuel charge is returned to the province or territory where it is collected. The Government of Canada does not keep any direct money from pollution pricing. For Yukon and Nunavut, the money is returned to their territorial governments. For the other provinces, the money is returned directly to individuals, farmers, small- and medium-sized businesses and Indigenous governments." (https://www.canada.ca/en/environment-climate-change/services/climate-change/pricing-pollution-how-it-will-work/putting-price-on-carbon-pollution.html).

Figure 22. Canada: Transition Scenarios Macro Variables

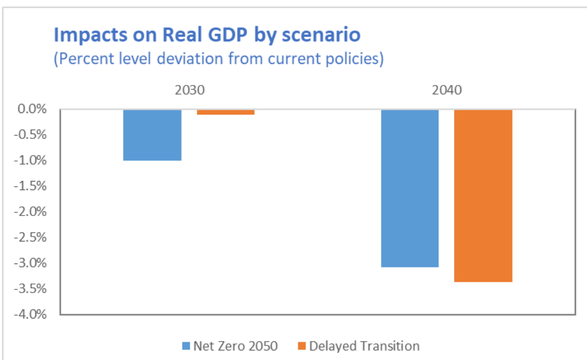
Carbon price (CAD)



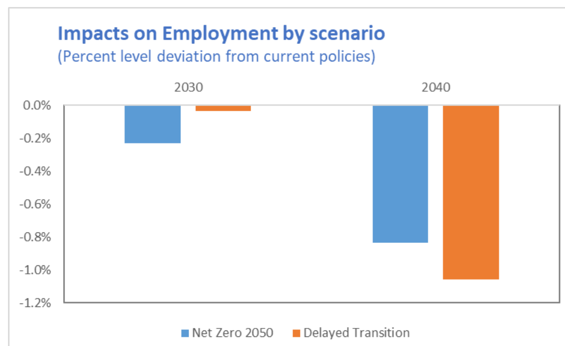
Total GHG emissions (Metric Tons of Carbon Dioxide Equivalent)



GDP losses (Percent level deviation from CP in 2030 and 2040)



Unemployment (Percent level deviation from CP in 2030 and 2040)



Source: IMF staff calculation.

58. To guide the micro simulation, the emphasis is placed on scenario-specific sectoral variables. The FSAP considered 16 different economic sectors (Table 4), based on the scope of the analysis and data availability, as discussed below. Sectoral variables include inter-industry relationships, price adjustments resulting from carbon taxes as well as from other policies, and global demand and supply drivers from international trade.

59. Under the Net Zero 2050 and DT scenarios, output would decrease for most sectors relative to the baseline, with some variations. The non-renewable electricity generation sector output declines substantially relative to the baseline as electricity production transitions to renewable sources. The oil and gas sector is also particularly affected. By contrast, renewable energy output increases significantly.[29] Intermediate input exhibits similar patterns. Total emissions decrease significantly for every sector except for electronic equipment and renewable energy, which experience output growth relative to the baseline pushing their total emissions slightly higher (Figure 23).

[29] The renewable energy sector (n. 13) includes both renewable electricity generation (nuclear, hydro, wind, solar, and others) and electricity transmission and distribution.

Table 4. Canada: Transition Analysis Sectoral Classification

FSAP Sectors				IMF-ENV sectors	
No.	Sector Name	Subsectors	Broad Sectors	code	name
1	Agriculture		Agriculture	cro-a	All Crops (cro)
			Agriculture	lvs-a	Livestock (lvs)
			Agriculture	frs-a	Forestry (frs)
			Agriculture	fsh-a	Fisheries (fsh)
2	Oil & Gas	Oil	Mining	oil-a	Crude Oil extraction (oil)
		Gas	Mining	gas-a	Natural gas (gas)
3	Other mining		Mining	OMN-a	Other extraction activities (OMN)
4	Food Products		Manufacturing	fdp-a	Food Products (fdp)
5	Paper products & publishing		Manufacturing	ppp-a	Paper products & publishing (ppp)
6	Chemical products		Manufacturing	crp-a	Chemical products (crp)
7	Metals manufacturing		Manufacturing	nfm-a	Ferrous metalsl (i_s), Metals nec (nfm)
			Manufacturing	i_s-a	Metal products (fmp)
8	Fabricated metal products		Manufacturing	fmp-a	Fabricated metal products (fmp)
9	Electronic equipment		Manufacturing	ele-a	Electronic equipment (ele)
10	Transport Equipment		Manufacturing	mvh-a	Transport Equipment (mvh)
11	Other manufacturing		Manufacturing	oma-a	Other manufacturing activities (oma)
12	Electricity Generation - Non-renewable	Coal powered electricity	Services	clp-a	Coal powered electricity (clp)
		Oil powered electricity	Services	olp-a	Oil powered electricity (olp)
		Gas Powered electricity	Services	gsp-a	Gas Powered electricity (gsp)
13	Electricity Generation Renewable and Electricity transmission & distribution	Nuclear power	Services	nuc-a	Nuclear power (nuc)
		Hydro power	Services	hyd-a	Hydro power (hyd)
		Wind power	Services	wnd-a	Wind power (wnd)
		Solar power	Services	sol-a	Solar power (sol)
		Other power	Services	xel-a	Other power (xel)
		Electricity transmission & distribution	Services	etd-a	Electricity transmission & distribution (etd)
14	Construction		Services	cns-a	Construction (cns)
		Land transport	Services	otp-a	Land transport (otp)
	Transport	Water transport		wtp-a	Water Transport (wtp)

Sources: IMF staff calculation. Note: the table reports the 16 sectors designed by the FSAP team for the transition risk analysis and the corresponding IMF-ENV sectors.

Figure 23. Canada: Transition Scenarios Sectoral Variables

Output Impacts (Percent level deviation from CP in 2040)

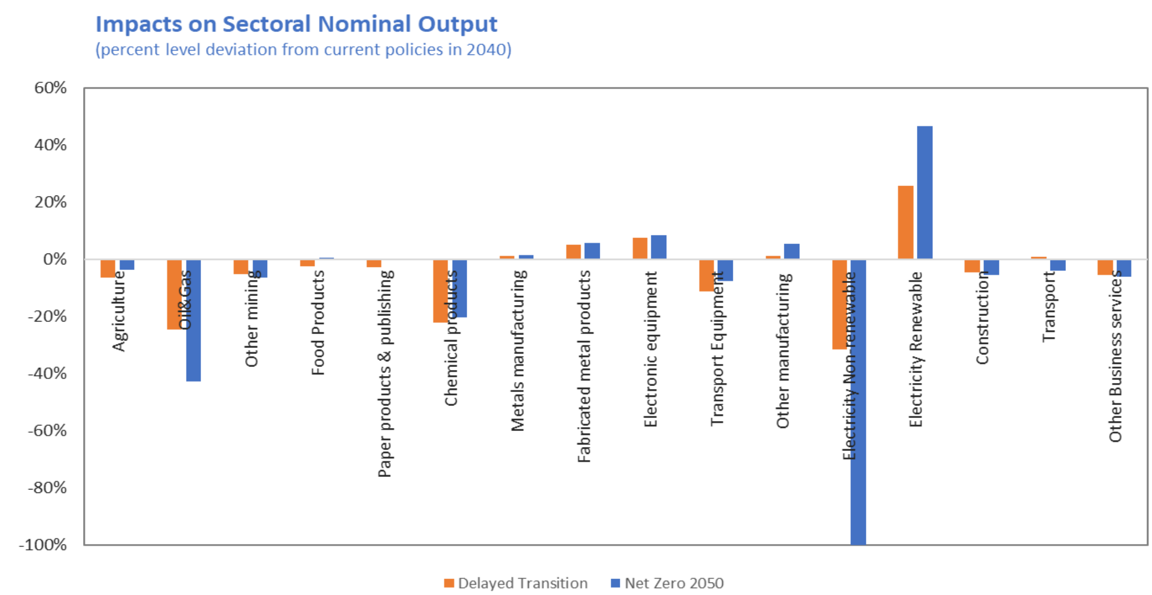
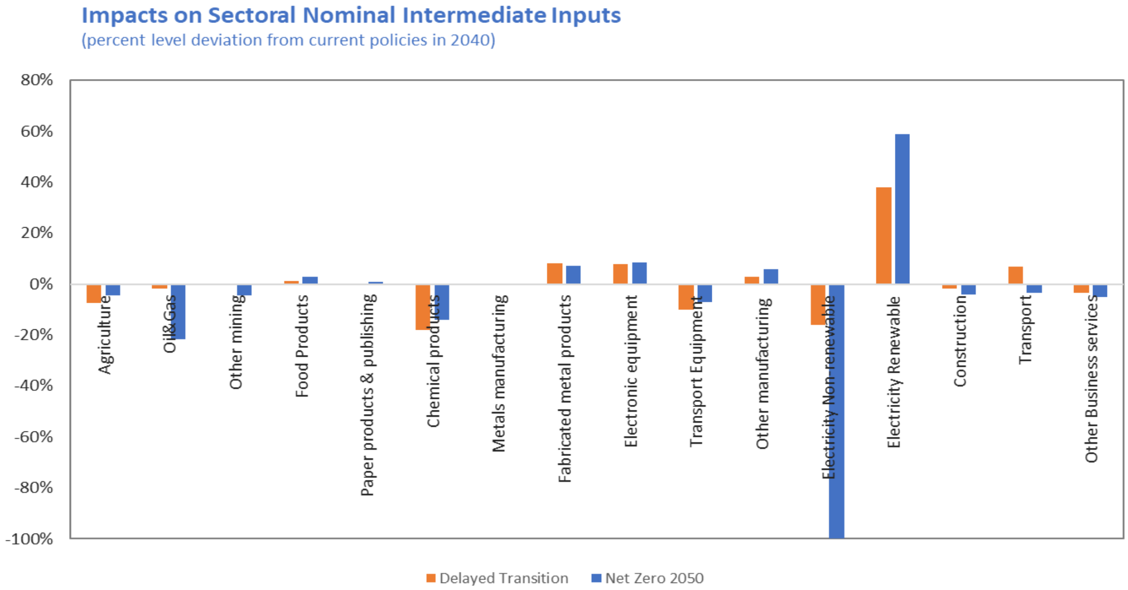
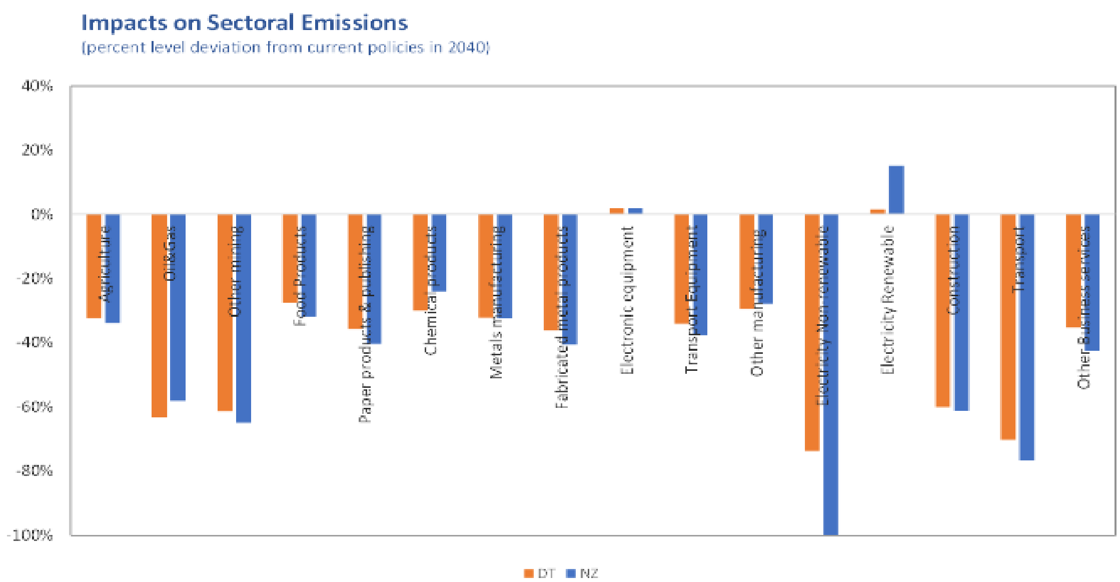


Figure 23. Canada: Transition Scenarios Sectoral Variables (concluded)

Intermediate Inputs Impacts (Percent level deviation from CP in 2040)



Emissions Impacts (Percent level deviation from CP in 2040)



Source: IMF staff calculation.

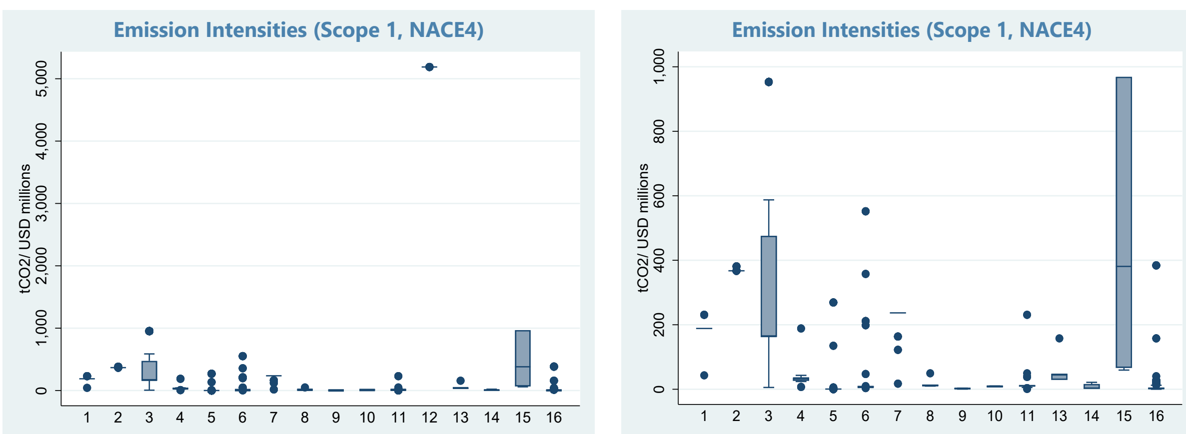
Firm Module

60. The firm-level module incorporates a micro-simulation framework leveraging firm-level data. This framework is designed to generate trajectories for firm-level risk metrics, taking into account the various scenarios' outputs from the IMF-ENV model.

61. The firm module adopts three main sources of micro data for Canadian NFCs. These consist of: i) profit and loss (P&L) and balance sheet data from Moody's Orbis database, ii) PD data from CreditEdge Moody's, and iii) emissions data from Intercontinental Exchange (ICE). First the team sourced P&L and balance sheets data from Moody's Orbis. The initial Orbis dataset has close to one million entities domiciled in Canada across all years. However, only less than one percent report balance sheet and P&L data are necessary for the model simulation.[30] After applying several filters, the Orbis dataset between 2000-2022 is around 5,000 firms.[31] Second, the team sources firms' PDs from Credit Edge, which contains around 4,000 firms across 2000-2024. The intersection between Orbis and Credit Edge data used for firms' PD modelling is around 2,150 firms. Finally, the team sourced emissions data (scope 1) from ICE. The team adopted the industry-median emissions intensities data (at NACE4 level) for the North America region (Figure 24).

Figure 24. Canada: Sectors Emission Intensities

All sectors | *Excluding energy non-renewable*



Sources: ICE and IMF staff calculation.

62. A "Time 0" (T0) database was constructed to anchor the micro simulation at the outset. In order to construct a "steady state" dataset, the team only kept data from recent years (2018–23). Flow variables were constructed as 3-year averages, while for stock variables the latest available year's observations were adopted. Observations from sectors that contained very few firms

[30] As a result, the Orbis dataset is not fully representative of the Canadian NFC sector.

[31] Only non-financial firms were kept, excluding financial and insurance activities, public administration, and activities of households as employers. Only firms with non-missing balance sheet, income statement, and sector data were kept. Observations from 2020 were dropped to reduce the COVID-19 distortions.

and correspond to an insignificant share of banks' loan portfolios were dropped. The final T0 dataset consists of 2,245 firms (Table 5).

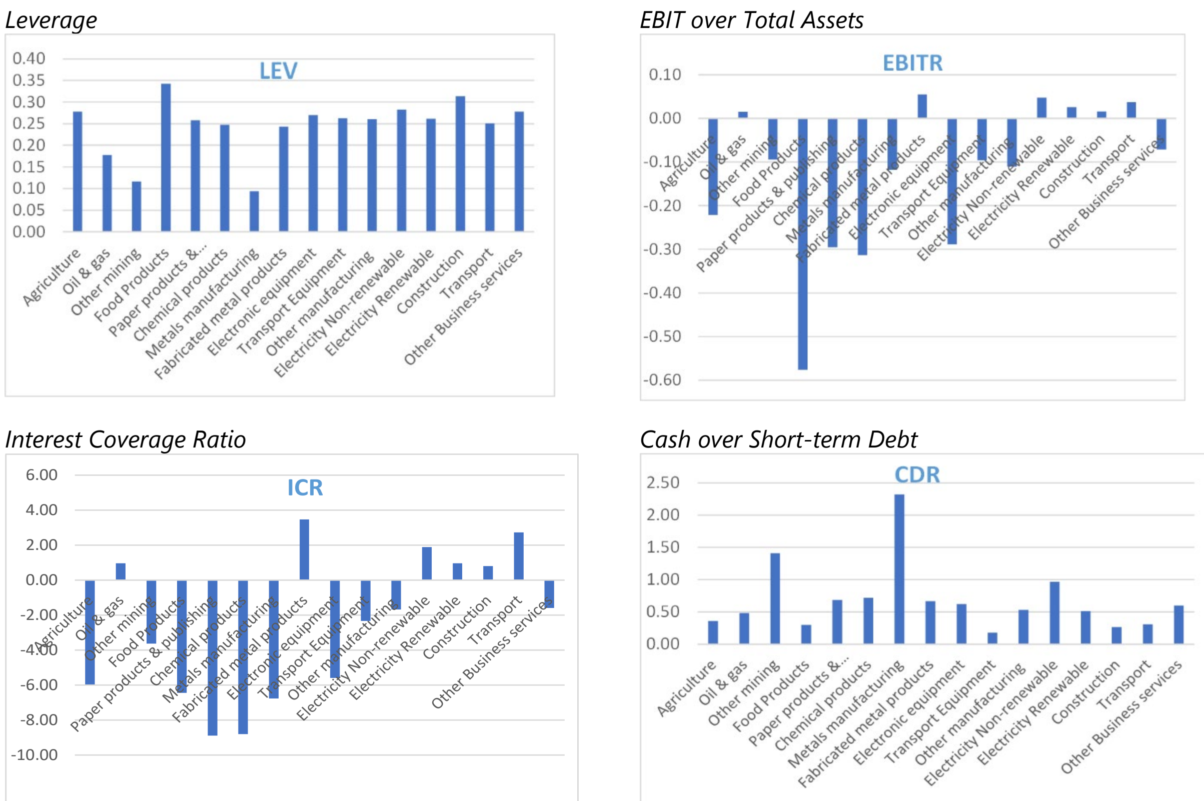
63. Four variables were used to capture firms' financial health in terms of solvency and liquidity. These are: i) leverage (LEV) defined as debt over total assets, ii) earnings before interest and taxes (EBIT) over total assets (EBITR), iii) interest coverage ratio (ICR) defined as EBIT over interest expense, iv) cash debt ratio (CDR) defined as cash over short-term debt. Most sectors in the T0 sample have low or negative profitability and negative ICR, that is, not sufficient earnings to cover interest payments (Figure 25). The oil and gas sector is one of the sectors with low leverage and positive profitability at T0. Note that the Orbis sample consists almost entirely of listed firms, which may not be fully representative of the loan portfolios of DTIs. Those portfolios likely contain a significant share of smaller firms, which are likely to have less diversified cash flow sources and smaller financial buffers. As a result, the risk analysis based on the Orbis sample presented here may underestimate the adverse impact on DTIs' actual loan portfolios.

Table 5. Canada: Transition Risk Micro Data T0

Sector Classification		Number of Firms (full sample)		Number of Firms (T0 sample)		Total Assets USDmm (T0 sample)	
No	**Name**	**Count**	**Share**	**Count**	**Share**	**Amount**	**Share**
1	Agriculture & forestry	39	0.8%	25	1.1%	15,972	0.5%
2	Oil & gas	447	9.0%	149	6.6%	317,198	10.8%
3	Other mining	1,010	20.3%	327	14.6%	169,529	5.8%
4	Food Prod manuf	116	2.3%	72	3.2%	89,278	3.0%
5	Paper prod & publishing manuf	315	6.3%	176	7.8%	50,090	1.7%
6	Chemical products manuf	326	6.6%	217	9.7%	67,132	2.3%
7	Metals (fer&non-fer) manuf	1,110	22.3%	476	21.2%	268,924	9.1%
8	Fabricated metal prod manuf	30	0.6%	12	0.5%	12,046	0.4%
9	Electronic equipment manuf	162	3.3%	73	3.3%	35,750	1.2%
10	Transport equipment manuf	33	0.7%	16	0.7%	39,438	1.3%
11	Other manuf activities	215	4.3%	104	4.6%	75,654	2.6%
12	Elect Gen-NonRE	11	0.2%	6	0.3%	86,488	2.9%
13	Elect Gen-RE & Elect T&D	50	1.0%	23	1.0%	220,686	7.5%
14	Construction	37	0.7%	16	0.7%	5,676	0.2%
15	Transport	42	0.8%	24	1.1%	290,878	9.9%
16	Other Busi services	1,024	20.6%	529	23.6%	1,194,891	40.6%
TOTAL		**4,967**	**100.0%**	**2,245**	**100.0%**	**2,939,631**	**100.0%**

Sources: Moody's Orbis and IMF staff calculation.

Figure 25. Canada: Firms' Characteristics at T0



Sources: Moody's Orbis and IMF staff calculation. The charts report the median for firms in each sector.

64. These variables are used in the PD model to simulate firms' PDs based on the stock and flow-oriented Merton model rationale. The PD model consists of a sector-level fixed effects panel econometric equation:

$$logit(PD_{ft}) = \alpha_f + \beta LEV_{ft} + \gamma ICR_{ft} + \delta EBITR_{ft} + \theta CDR_{ft} + \varepsilon_{st}$$

Where f denotes firm, s denotes sector, and t time. Macro-financial variables were not included in the right-hand side because they already feed into the other regressors. This model is based on the simplifying assumption that there is a linear relationship between the independent variables and the logit value of PD for all firms in the sample.

65. The PD model results indicate that leverage plays a prominent role. The other variables, while still significant, have much smaller coefficients (Table 6). Intuitively, an increase in leverage implies higher PDs, while all the other variables have a negative impact on PDs. The PD model was estimated using Credit Edge data for listed firms. This model was used for point-in-time (PiT) PDs, while through-the-cycle (TTC) PDs were computed as long-term averages of PiT PDs.

Table 6. Canada: Probability of Default Model Results	
RHS	**Logit (PD)**
LEV	3.280*** (.0770)
ICR	-.0028*** (.0003)
EBITR	-.5354*** (.0362)
CDR	-.0144*** (.0022)
cons	5.288*** (.0266)
Observations	17,060
Within R^2	0.2079
Sources: Moody's Credit Edge and IMF staff calculation. Notes: Standard errors are in parentheses. *** p<.01. ICR, EBITR and CDR are winsorized at 5 and 95 percent, LEV is winsorized at 1.	

66. LGDs were derived from PDs using the Frye and Jacobs (2012) model:

$$\mathrm{LGD_{ft}} = \frac{\Phi(\Phi^{-1}(\mathrm{PD_{ft}}) - \mathrm{k_f})}{\mathrm{PD_{f,t}}}\text{ ; where } \mathrm{k} = \frac{\Phi^{-1}(\overline{\mathrm{PD_f}}) - \Phi^{-1}(\overline{\mathrm{PD_f}} \times \overline{\mathrm{LGD_f}})}{\sqrt{1-\rho}}$$

Where Φ denotes the standard normal cumulative distribution function, k_f is a parameter being driven by TTC PDs and LGDs, denoted respectively as $\overline{\mathrm{PD_f}}$ and $\overline{\mathrm{LGD_f}}$, and the asset correlation parameter ρ. At T0 LGDs PiT were set as the industry-level LGDs using DTIs' data (weighted average across all DTIs using their NPL stocks as weights). Then this formula was used to derive TTC LGDs from TTC PDs and PiT PDs and LGDs.

67. Firms' P&L modelling involves linking the transition scenarios' sectoral variables to firm-level variables though 3 key channels. First, firms' sales revenues evolve in line with sectoral output growth. Second, firms' operating expenses follow sectoral intermediate input growth.[32] Third, firms' emissions evolve in line with sectoral emissions path. The direct cost of firms' emissions is subtracted from their EBIT (Table 6). Hence, firms in heavy-emitting sectors experience the highest financial impact, at least initially. Carbon pricing impacts firms also indirectly through their impact on other sectoral input-output paths.

[32] It was not possible to divide operating expenses between inputs cost and labor cost due to data gaps in Orbis.

Table 7. Canada: Firm Profit and Loss Modelling Overview

P&L Component	Model Approach
Sales revenue [A]	Align with output projections from the IMF ENV
Operating expenses [B]	Align with intermediate input projections from the IMF ENV
Financial revenue [G]	Moving proportionally with sales revenue
Financial expense (interest paid) [H]	Moving proportionally with debt

EBIT = = [A] – [B] - *Direct emissions costs (firm's emission (scope1) × carbon price)*

EBT = Earnings after net financial income and before tax = EBIT + [G] - [H]

NI = Earnings after net financial income and tax = EBT - tax

ICR = EBIT / [H]

Source: IMF staff calculation.

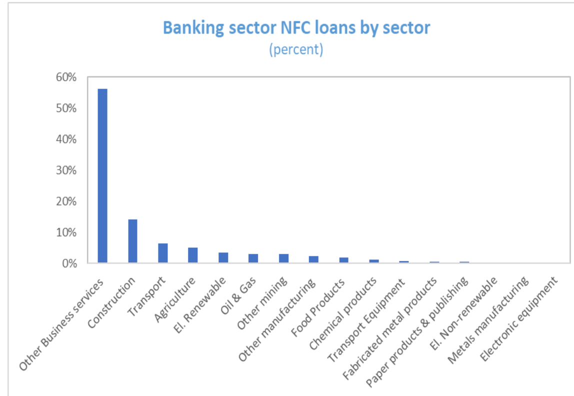
68. **As profitability erodes, firms may need to borrow more to continue operations, increasing their leverage.** Post-tax profits are added to firms' cash balances, as well as to their total assets. When a firm's cash turns negative during the simulation, firms take on more debt to cover the shortfall. Increasing leverage, which is the main driver in the PD model, drives up firms' PDs. As there are no options to deleverage, this creates a negative cycle pushing up PDs of firms in sectors which start from low profitability or are particularly negatively affected by the transition.

Bank Module

69. **The bank module adopts confidential data on DTIs' outstanding NFCs loan portfolios across various industry segments.** OSFI and AMF provided loan portfolio data for the 7 systemic DTIs as of Q3: 2024. The dataset adopted in the FSAP was constructed from borrower-level data (called Rapid 2) aggregated to the 16 sectors designed for the exercise. The FSAP team provided to the authorities a mapping between the 16 sectors to the North America Industry Classification (NAICS) codes adopted in DTIs' reporting. The dataset includes exposures to NFCs as well as PDs and LGDs. Specifically, the analysis adopted PDs for economic capital as PiT PDs and PDs for regulatory capital as TTC PDs. PiT LGDs were computed as the allowance for expected credit losses for stage 3 loans over borrower total outstanding and Downturn LGDs as the LGD for regulatory purposes. The data only covers NFCs loans in excess of CAD 10 million, leaving out smaller exposures, which are more likely to come from smaller firms, potentially more vulnerable to financial shocks. The FSAP team estimated that coverage of this dataset is 60 percent of the total DTI sector NFC loans.

70. The diversification in industry composition of the DTI sector portfolio, as well as the relatively small concentration in high emitting sectors, could limit the vulnerability of the DTI sector to transition risks. The largest share (55 percent) of exposures of the aggregate DTI sector is towards the "other business services" sector, followed by construction (14 percent). Heavy emitting sectors such as non-renewable electricity generation, oil and gas, transport, other mining, represent approximately 13 percent of the total loan portfolio (Figure 26). This remains true for individual DTIs, with little variation across the seven institutions. However, as mentioned above, the sample of the study is covering only 60 percent of the DTIs' portfolios and is biased towards larger exposures. Further, when looking at a broader set of DTIs included in the SCSE, authorities find larger concentrations in sectors exposed to transition risks. For example, oil and gas alone represents 6 percent of their exposures.

Figure 26. Canada: Banks Non-Financial Corporate Loans by Sector



Sources: OSFI and AMF Rapid 2 data, IMF staff calculation.

71. The analysis estimates DTIs' credit losses under the transition scenarios using the results from the firms' module. Firms' PDs and LGDs were aggregated at the 16 sector-level, weighing each firm by its total assets. These sectoral PDs and LGDs were then used to simulate forward in time PDs and LGDs for the seven DTIs, which were anchored at T0 in reported data.

72. The calculations of DTIs' credit losses follow a simplified approach.[33] The evolution for the non-performing loan stock for a bank b's exposure to sector n at horizon h ($RRPPD_{n,b,h}$) is calculated as follows:

$$NPL_{n,b,h} = NPL_{n,b,h-1}(1 - WROR - CURER) + PD_{n,b,h}\, PL_{n,b,h}\,,$$

where performing exposures ($PL_{n,b,h}$) are computed as a residual of gross exposures and the non-performing exposure stock ($L_{n,b,h} - NPL_{n,b,h}$). The write-off rate (*WROR*) and the cure rate (*CURER*) are set to 100 percent and zero percent, respectively.[34] The NPL portfolios is used to compute provisions, denoted $PROV^{NPL}_{n,b,h}$, as follows:

$$PROV^{NPL}_{n,b,h} = LGD_{n,b,h} \times NPL_{n,b,h}.$$

[33] Results calculate annual expected losses and do not follow the IFRS 9 methodology.

[34] As explained in Gross et al. (forthcoming): "The cure rate being set to zero reflects the interpretation of PDs as being closer to ultimate bankruptcy rates, not to a 90-day past-due criterion-based default rate. The NPL write-off rate being set to 100 percent is instrumental for not having to design the rate such that NPL ratios, in the long run, do not diverge."

The provision flows, that is, loan losses ($LL_{n,b,h}$), in turn, are computed as:

$$\mathrm{LL}_{\mathrm{n,b,h}} = \mathrm{PROV}^{\mathrm{NPL}}_{\mathrm{n,b,h}} - \mathrm{PROV}^{\mathrm{NPL}}_{\mathrm{n,b,h-1}} + \mathrm{WRO} \times \mathrm{LGD}_{\mathrm{n,b,h}} \times \mathrm{NPL}_{\mathrm{n,b,h-1}}.$$

Data and Methodological Limitations

73. Results based on the approach described above should be interpreted with caution given caveats and limitations of the analysis. In terms of data, the DTIs' NFC loan portfolio data is restricted to large loans, hence leaving out smaller and potentially more vulnerable firms, which are less likely to absorb financial shocks. Firm level data was considered representative of DTIs' NFC loan portfolios at sectorial level. There are also substantial uncertainties surrounding firms' emission intensity levels. In terms of modelling, the firms' simulation does not capture all channels of transmission of transition risks to individual firms. Further, the banks' simulation focuses on only one channel, credit risk from NFCs, ignoring other risk channels. An analysis of the full economic and financial impact of transition scenarios on the entire DTIs' balance sheet (using the so-called macro-approach in Adrian et al. 2022) would likely lead to larger impacts. Moreover, the scenario ends in 2040 when the adverse impact of a DT starts to become visible. Extending the analysis beyond 2040 would likely present a less sanguine picture about the adverse impact of a DT.

Results

74. Several factors contribute to the results of the transition risk analysis: i) different transition scenarios at sectoral level, ii) firms' emissions intensities which drive different costs of carbon pricing, iii) firms' initial risk characteristics, iv) DTIs' exposures to different industries, and v) DTIs' initial loan portfolio risk profile.

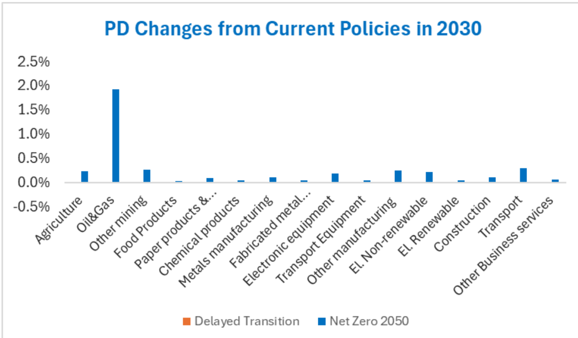
75. Based on the applied methodology, under the transition scenarios, sectoral PDs and LGDs would generally increase modestly but with significant variation across sectors (Figures 27, 28 and 29). Notable adverse impacts are observed for the oil and gas and non-renewable electricity generation sectors. These sectors experience the largest absolute (Figure 27) and relative (Figure 29) increases, respectively, in PDs under the two transition scenarios relative to baseline in 2040. These two sectors are indeed the sectors with the largest emission intensities by far (Figure 24). Among the other sectors, construction and mining also stand out.

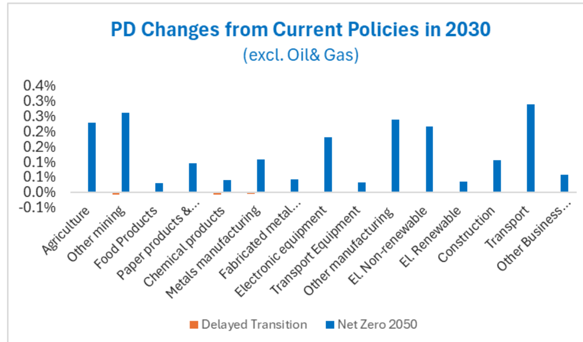
76. The impacts of the two scenarios have different timing. The adverse impact is larger under Net-Zero 2050 than under DT for most of the simulation period. This is driven by the fact that, unlike DT, under Net-Zero 2050 stringent climate policies are implemented from the beginning of the simulation period. Sectors' PDs increase under the Net-Zero 2050 scenario relative to the baseline in 2030. DT is not yet impactful in 2030. However, when the DT initiates after 2030, PDs start increasing. By 2040 the DT impacts overcome the ones under Net Zero 2050 for most sectors. LGDs follow similar dynamics.[35]

[35] The relative changes in PDs and LGDs at the bank-level are broadly in line with the aggregate sector-level relative PD and LGD changes reported in the Bank of Canada transition risk analysis study, see Bruneau et al (2023).

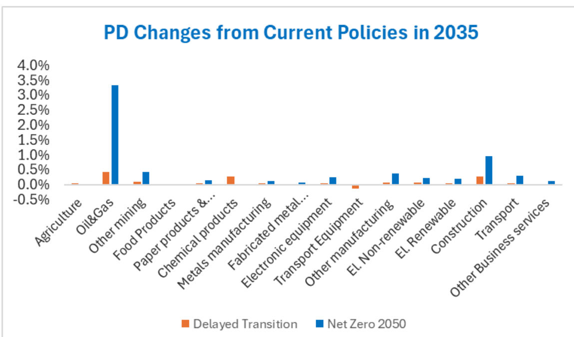
Figure 27. Canada: Firms' Probability of Defaults Level Change

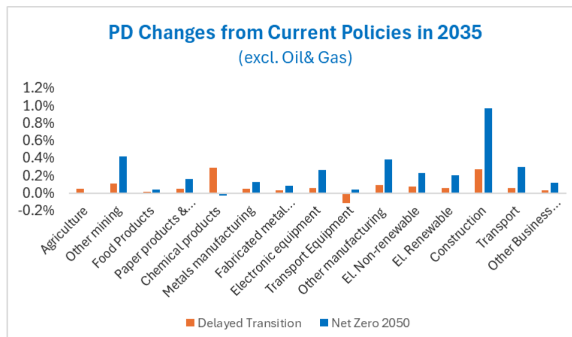
PDs level changes in 2030 | *PDs level changes in 2030 excluding Oil & Gas*



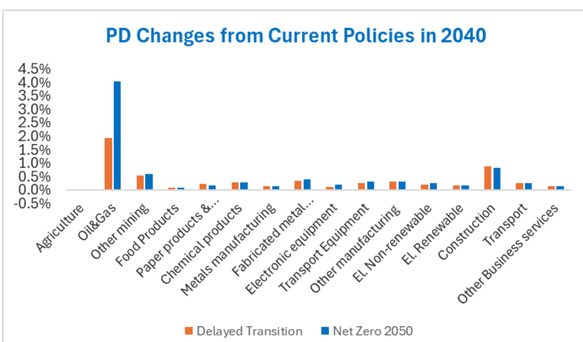


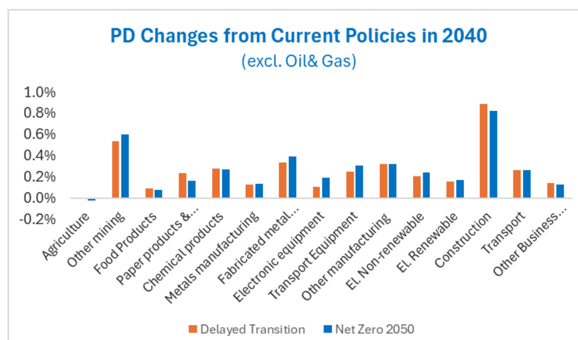
PDs level changes in 2035 | *PDs level changes in 2035 excluding Oil & Gas*





PDs level changes in 2040 | *PDs level changes in 2040 excluding Oil & Gas*

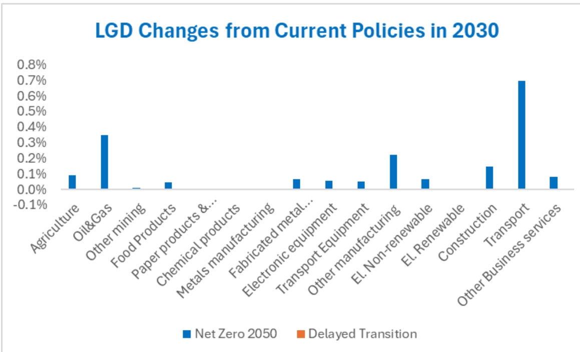




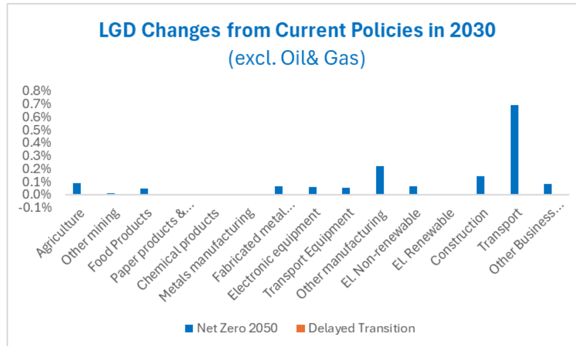
Sources: IMF staff calculation. The charts report the weighted average of firms' variables for each sector, using total assets for weights.

Figure 28. Canada: Firms' Loss Given Defaults Level Change

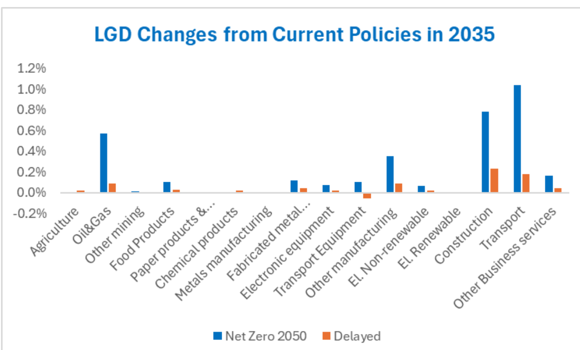
LGDs level changes in 2030



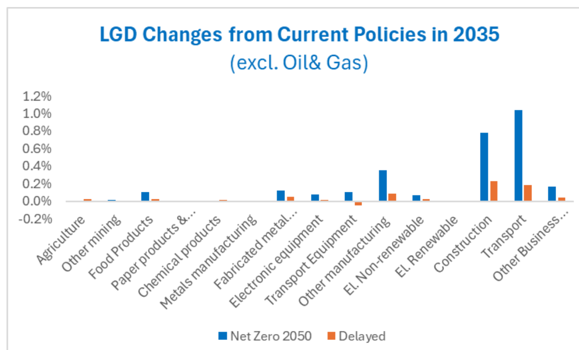
LGDs level changes in 2030 excluding Oil & Gas



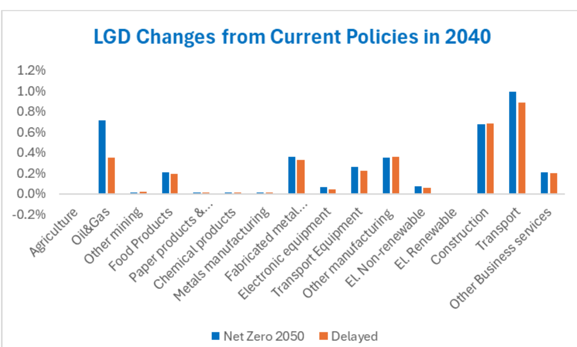
LGDs level changes in 2035



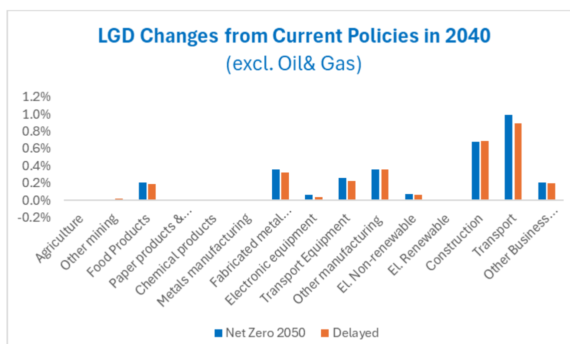
LGDs level changes in 2035 excluding Oil & Gas



LGDs level changes in 2040



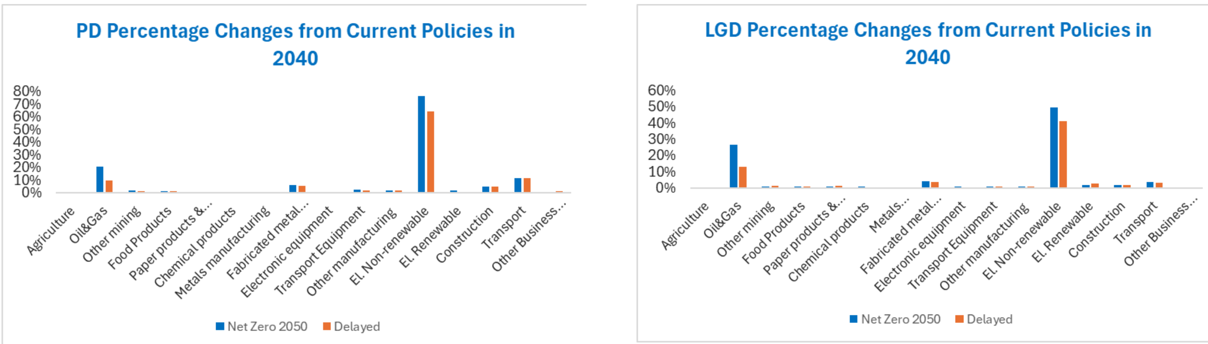
LGDs level changes in 2040 excluding Oil & Gas



Sources: IMF staff calculation. The charts report the weighted average of firms' variables for each sector, using total assets for weights.

Figure 29. Canada: Firms' Probability of Defaults and Loss Given Defaults Percentage Change

PDs percentage changes in 2040 *LGDs percentage changes in 2040*



Sources: IMF staff calculation.
Note: The charts report the weighted average of firms' variables for each sector, using total assets for weights.

77. DTIs' credit losses under DT begin to exceed the ones under Net Zero in 2040. DTIs' credit losses are estimated to increase between 3.8 and 7.1 percent under the Net Zero 2050 and DT scenarios relative to CP by 2040 (Figure 30), depending on the bank and scenarios. The cumulative impact is still greater under the Net Zero 2050 scenario; however, this is driven by the fact that the simulation period ends in 2040, just as the adverse effects of the DT—with its accelerated transition actions—begin to exceed those of the Net Zero 2050 scenario.

Figure 30. Canada: Deposit Taking Institutions' Loan Losses

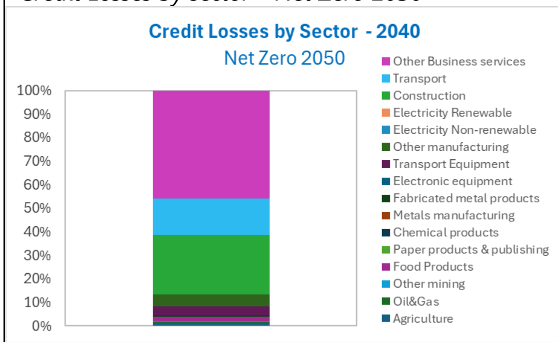
Source: IMF staff calculation.

Note: The chart reports the box plot of the loan losses change for the seven institutions.

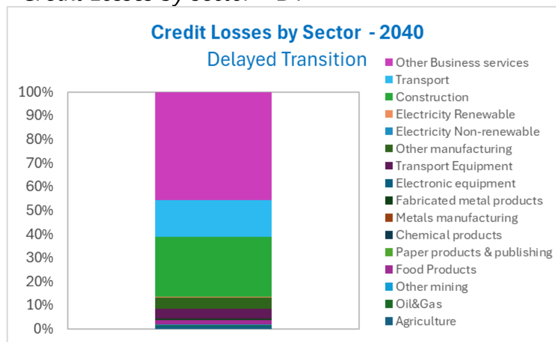
78. "Oil and gas" and "electricity non-renewable" sectors drive relative changes in DTIs' credit losses. Credit losses are largely driven by the sectors where DTIs have their largest exposures, namely other business services, transport and construction. However, looking at the relative change in losses by sector highlights that oil & gas and electricity non-renewable sectors, the two heaviest emitters, are the ones most impacted by the transition in the banks' NFC portfolio (Figure 31).

Figure 31. Canada: Deposit Taking Institutions' Credit Losses by Sector

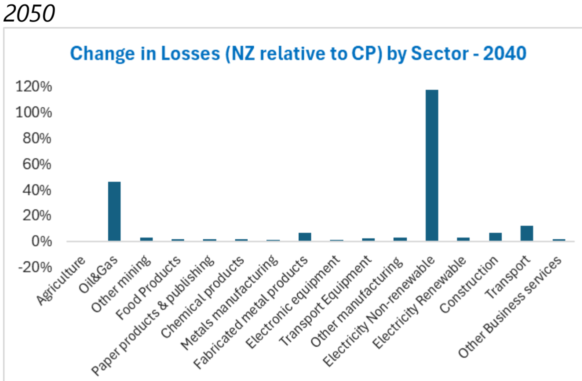
Credit Losses by sector—Net Zero 2050



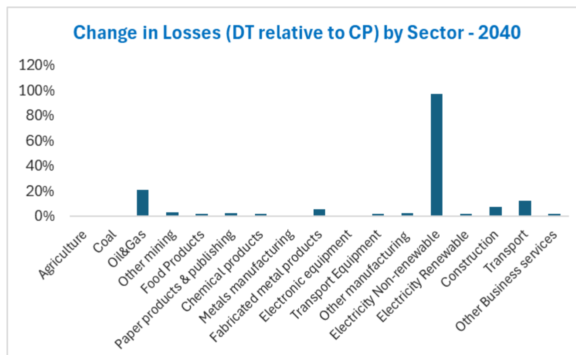
Credit Losses by sector—DT



Relative change in credit losses by sector—Net Zero 2050



Relative change in credit losses by sector—DT



Sources: IMF staff calculation.

Annex I. First Best Methodology for Wildfire Risk Analysis

1. Physical risks arise as the interaction of three components: hazard, exposure and vulnerability. Changes in both the climate system and socioeconomic processes including adaptation and mitigation are drivers of hazards, exposure, and vulnerability.

2. In terms of exposure, the FSAP analysis is interested in residential properties in Canada which serve as a collateral for DTIs' mortgages. The ideal location information would be the most granular possible that is, address level, which would then be geocoded to specific latitude and longitude. Information on the structure of the house, such as the type of roof and whether the house has exposed exterior vents, as well as the building code would also be important to accurately reflect wildfire risk. Ideally, one would also have an idea of how these exposures could change in the future, both in terms of structure (as building and fire codes change), location (as population and urban development changes affect the distribution of residential properties in the country) and value.

3. In terms of the hazard data, the ideal measure would be the likelihood (probability for a location to experience a wildland fire) and intensity (amount of energy produced by a fire) of fires under current and future climate for different climate scenarios at a sufficiently granular geographic resolution across Canada. This is for instance the type of data, obtained from a probabilistic model Burn P-3 simulating a large number of fires under current climate, used in Erni et al. (2024). Wang et al. (2016) used the same model to simulate fire under future climate, as well as changes in fuels and ignitions, for an area in south-central British Columbia. Their results show that the future climate will increase the number of fires and fire-conducive weather, leading to widespread increases in burn probability in that region. Looking at a broader study area in Canada, Wang et al. (2020) find that fire size and annual area burned across Canada may increase by 20–64 percent and 25–93 percent respectively under future climate.

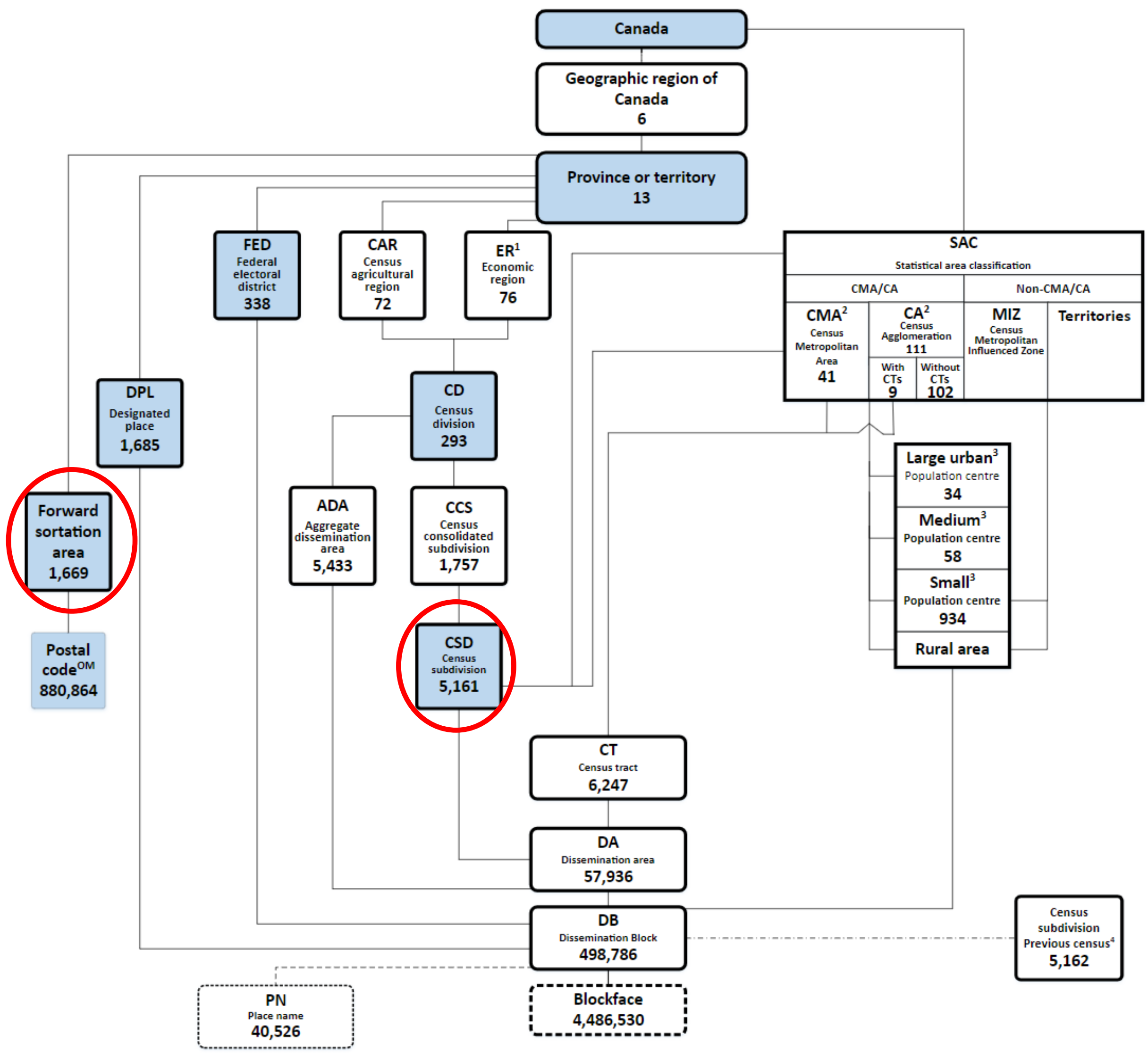
4. Future fire behavior will depend not only on changes in weather, but also in vegetation and ignition (Figure 2). Additional factors that could influence their change in the future are pest outbreaks and fire suppression as well as other actions to mitigate fire risks. However, there is still limited understanding of how these factors impact fire behavior in existing literature.

5. Finally, in terms of vulnerability that is, the propensity of the exposure to be affected by wildfire, one common tool used in the literature is a damage function quantifying the rate of damage of the exposure for varying levels of hazard intensity. Ideally, one would use wildfires' damage functions specifically calibrated for Canada and its residential buildings. These damage functions would account for the characteristics of the building, as well as the surrounding conditions such as vegetation and other structures.

6. Combining these three datasets together the analysis would estimate wildfire risk under current and future climate. Specifically, one would be able to quantify the expected economic losses to residential buildings under current and future fire activity in each location in Canada. Due to lack of these datasets, the FSAP team adopted a simplified methodology.

Annex II. Canada Hierarchy of Standard Geographical Areas

Figure 1. Canada: Hierarchy of Standard Geographic Areas for Dissemination, 2021 Census.



Source: Statistics Canada

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